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OSTEOTOMY OF THE SPINE FOR CORRECTION OF FLEXION DEFORMITY IN RHEUMATOID ARTHRITIS *

BY M. N. SMITH-PETERSEN, M.D., CARROLL B. LARSON, M.D., AND OTTO E. AUFRANC, M.D., BOSTON, MASSACHUSETTS

"Osteotomy of the Spine" is a slightly misleading title for this paper, but it is an intriguing one, effective in stimulating interest and curiosity. The operative procedure is confined to the laminae and articular facets and does not involve the vertebral bodies.

Summary of Recent Progress in Surgery of Rheumatoid Arthritis

In 1941 the authors were granted the assignment of "Operative Procedures for the Prevention and Correction of Deformities in Rheumatoid Arthritis", at the Massachusetts General Hospital. This assignment allowed us to evaluate acromioplasty, excision of the radial head, and excision of the distal end of the ulna for the relief of pain and restoration of function to the joints of the upper extremity.[1] The technique of arthroplasty of the hip has been improved, so that more nearly perfect mechanical joints can be shaped. Progress is also being made in mold arthroplasty of the knee.

Optimum Time for Surgical Procedures in Rheumatoid Arthritis

One problem has been constantly before us, and that is the question of the optimum time for surgical treatment. Up to the present time, the generally accepted opinion has been that surgery must wait until the active stage of the disease has passed. This waiting period is a period of gradually diminishing activities, commonly terminating in recumbency in the position of minimum pain. The results of diminished or absent function are atrophy of muscle and bone (loss of elasticity of ligaments, fascia, and intermuscular septa) and development of joint deformities. Surgery performed under these conditions is technically difficult; restoration of motion is slow; and the functional end result less satisfactory than when surgery is undertaken at a relatively early stage, while the disease is still active.

Analysis of Development of Flexion Deformity and Its Surgical Correction

Recumbency in the position of minimum pain commonly results in a flexion deformity of the spine sufficiently marked to interfere with the function of the lower extremities in standing and walking, and to make the sitting position one of strain and discomfort.

* Read at the Annual Meeting of The American Orthopaedic Association, Hot Springs, Virginia, June 2, 1944.

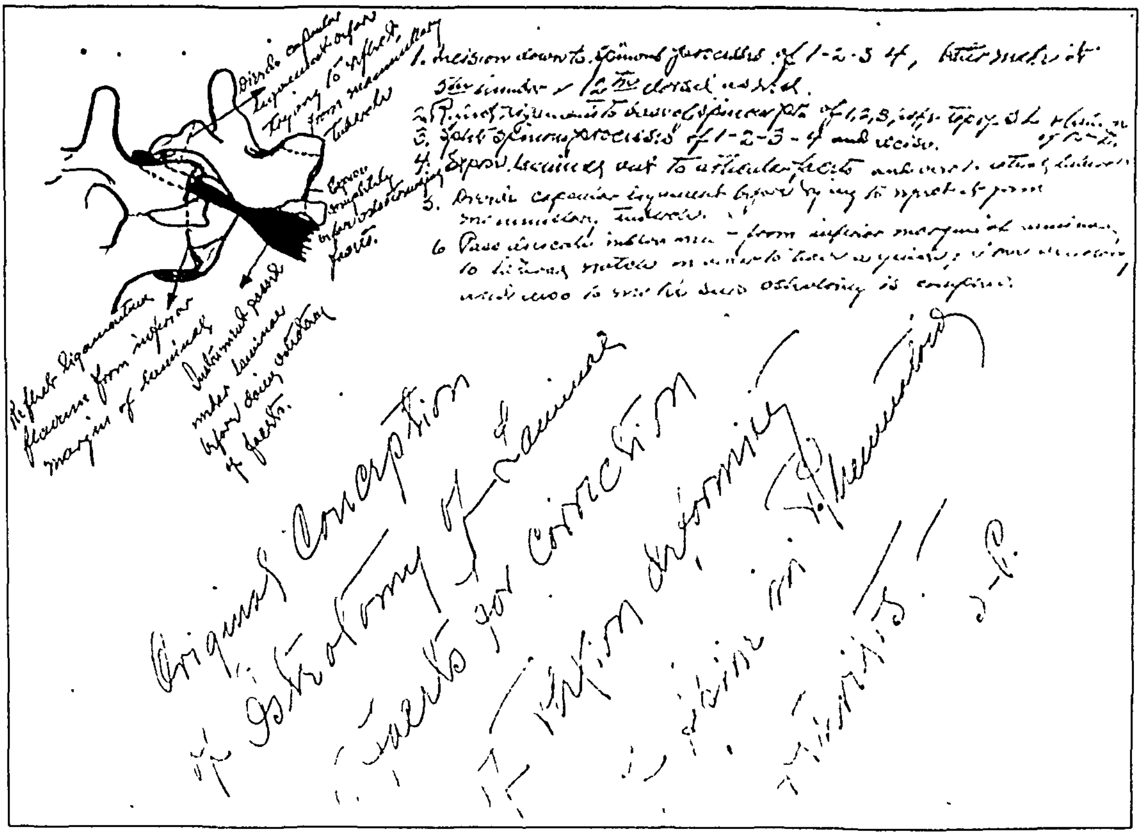


FIG. 1

Reproduction of sketch and notes made in preparation for the first osteotomy of the spine, March 1941.

Manipulation, followed by support, will improve many of these patients; it will not be of benefit after bony ankylosis of the articular facets and calcification of the longitudinal ligaments have occurred. Patients with ankylosis of both hips not infrequently present this latter extreme condition of the spine. After arthroplasties, the flexion deformity of the spine interferes to such an extent with function of the lower extremities that the problem of correction becomes most important. Analyzing the obstacles to correction, we came to the conclusion that the ankylosed facets, surrounded by overgrowth of bone, offered more resistance than any of the other spinal structures. Any surgical procedure for correction of the flexion deformity must, therefore, be aimed at the facets, articular processes, and adjacent laminae; osteotomy of these structures, with excision of sufficient bone, should allow corrective leverage to be transmitted to the intervertebral discs and longitudinal ligaments, overcoming whatever resistance these may present.

Preceding the first operation, a diagram was made and the operative steps were outlined (Fig. 1). It is rare that a surgeon is able to carry out a preconceived plan of operation, but in this case that was true; furthermore, the operation is even now essentially the same. Only six cases have been done; further experience may, and probably will, bring about improvement in the operative technique.

OPERATIVE TECHNIQUE

The lumbar region is more favorable than the thoracic, since the latter commonly presents ankylosed costovertebral joints rendering correction difficult, if not impossible. Thoracic osteotomy has been done in only one case; it resulted in subjective improvement, but there was no objective evidence of it.

Selection of the lumbar level or levels at which the osteotomy is to be performed depends on the roentgenographic findings; the less marked the ossification, the better the chance of correction.

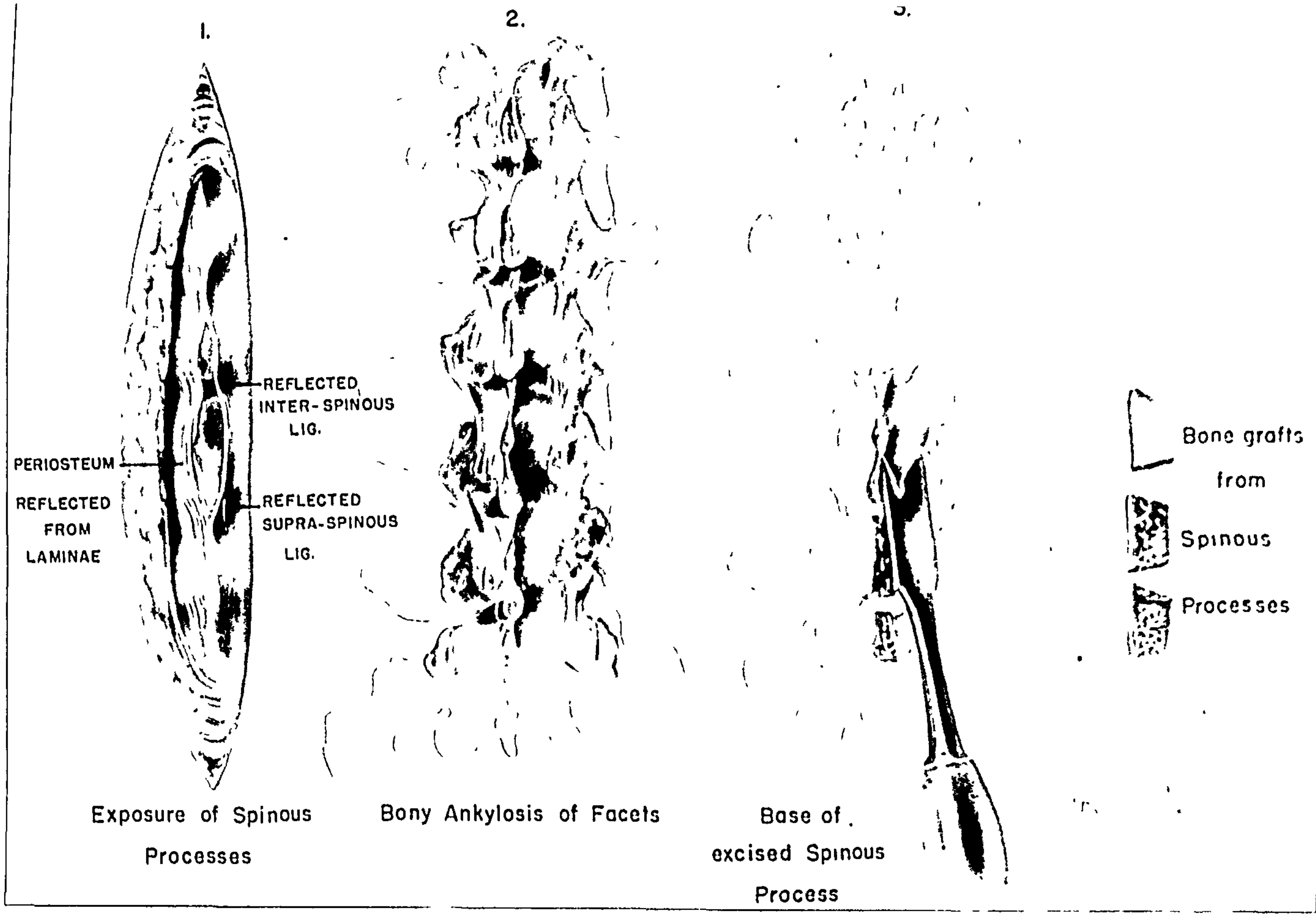


FIG. 2

1: Exposure and reflection of supraspinous and interspinous ligaments. Beginning reflection of periosteum with its muscular and ligamentous attachments from the spinous processes and laminae.
2: Drawing of specimen showing bony ankylosis of articular facets.
3: Two spinous processes have been osteotomized into lamellae, to be used as bone grafts; the third spinous process is being osteotomized in a similar manner.

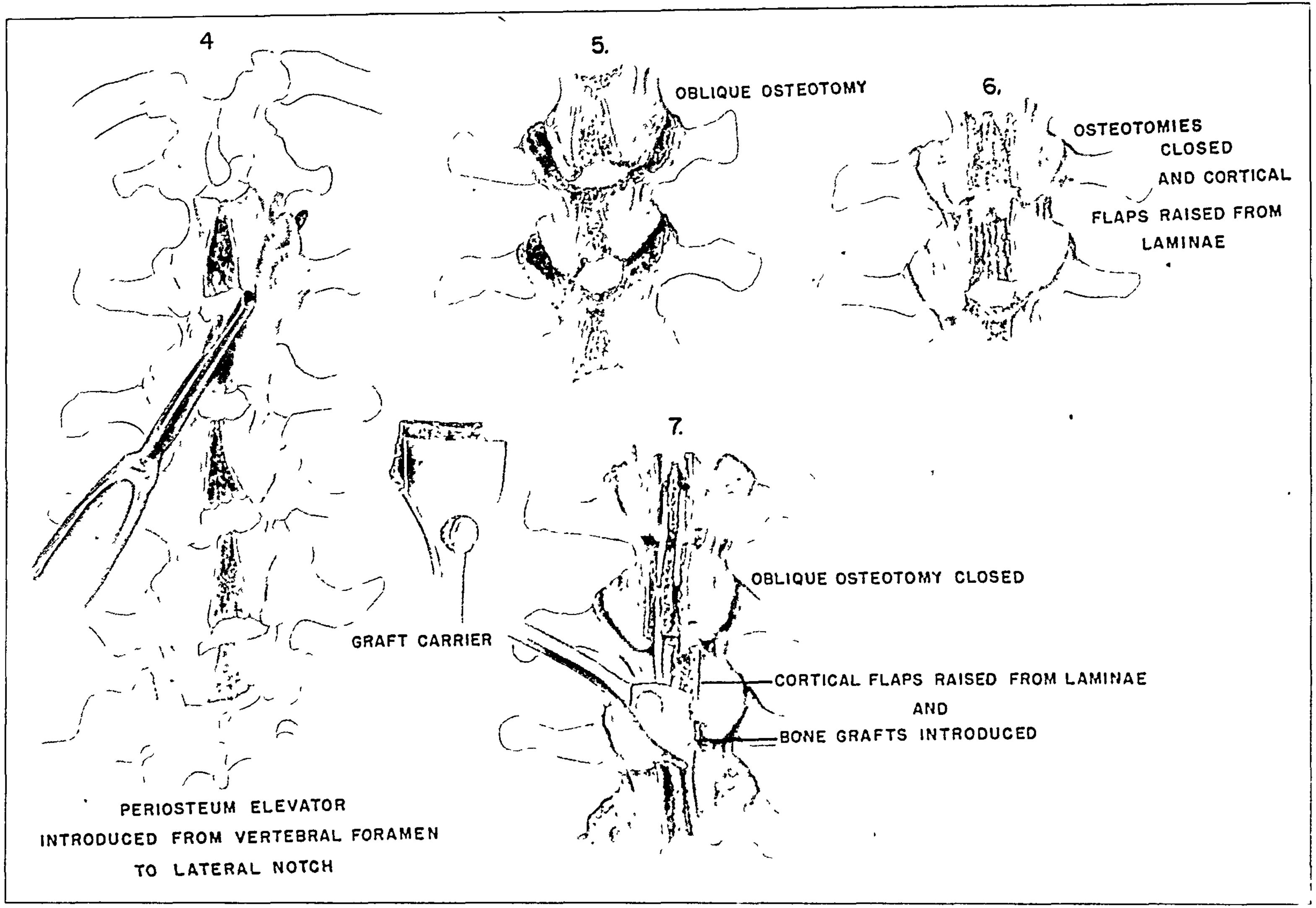


FIG. 3

4: Periosteum elevator has been introduced anterior to lamina and articular process; its point is seen at the intervertebral or lateral notch.

5: The oblique osteotomy has been completed at two levels. (The diagram is correct, but is misleading in so far as the space created is concerned,—there should be a space of one-quarter to three-eighths of an inch between the osteotomy surfaces.)

6: The head and foot of the operating table have been raised and the osteotomy spaces have been closed. Cortical lamellae have been raised from the laminae.

7: Bone grafts, obtained from the spinous processes, have been introduced into the laminae. The bone-graft carrier is shown in position.

Operative Steps

Through an incision in the mid-line, at least three lumbar spinous processes are exposed. Even if the osteotomy is performed at one level only, the spinous process above and below that level must be completely exposed and excised in order to allow adequate retraction (Fig. 2, *1*).

The second step consists of the incision and reflection of supraspinous and interspinous ligaments, followed by the subperiosteal reflection of muscle attachments from the spinous processes and laminae.

The spinous processes are then osteotomized into lamellae with a thin osteotome, and are excised at their bases (Fig. 2, *3*). This allows further reflection of the periosteum from the superior and inferior articular processes, exposing the intervertebral notch as well as the articular facets. The reflection of the periosteum must be accompanied by division of the muscular attachments to the ligamentum flavum.

By means of a periosteum elevator, the ligamentum flavum is detached from the inferior margin of the lamina and inferior articular process. The elevator is then advanced anterior to the lamina and inferior articular process until it appears in the lateral intervertebral notch just above the articular facet (Fig. 3, *4*); it serves as a guide to the direction of the osteotomy through the superior articular process of the vertebra below and the inferior articular process of the vertebra above. The osteotomy is done in an oblique plane, at an angle of approximately 45 degrees with the frontal plane (Fig. 3, *5*). The osteotomes should be narrow and thin-bladed; both straight and curved osteotomes are required. Gouges of the same type are sometimes useful. A rongeur with narrow jaws is indispensable. The osteotomy is performed at one, two, or three levels, depending upon the extent of new-bone formation in relation to the facets and intervertebral discs.

Upon completion of the osteotomy or osteotomies, leverage in the direction of extension is applied by raising the head and foot of the operating table very slowly. The gradual narrowing and final obliteration of the oblique spaces between the laminae and between the remnants of the articular processes marks the "high-spot" of the operation. The obliquity of the osteotomy ensures locking and prevents any serious displacement (Fig. 3, *6*).

By means of delicate osteotomes, bone flaps are raised from the laminae adjacent to the osteotomy, and the bone lamellae obtained from the spinous processes are inserted by means of a bone-graft carrier. These grafts bridge the gap between the laminae, and consequently hasten bony fusion in the corrected position (Fig. 3, *6* and *7*).

In closing the wound, close apposition of the split interspinous and supraspinous ligaments is important. If the approach is developed with proper regard for structures and structural planes, the closure and nature's repair of the wound are facilitated.

Postoperative Care

A plaster shell is applied and kept on for four to six weeks, followed by a plaster jacket or back brace, to be worn continuously for a year or longer. Since complete correction is never obtained, it is important to guard against recurring deformity by having the patient wear the brace part of the day for two or three years postoperatively. It is hardly necessary to emphasize the importance of exercises for control of posture, as well as for maintaining chest expansion.

ASPECTS OF OPERATIVE TECHNIQUE DEMANDING EMPHASIS

1. The operative procedure must not be belittled,—there are many points in the technique that we have found difficult.

2. In developing the approach, it is more important to follow structural planes and preserve hemostasis than to save a few minutes in operating time. The osteotomy is in itself difficult, and demands a dry field.

3. The spinous processes must be excised before an attempt is made to expose the articular processes and intervertebral notch.

4. The interspinous ligament and the ligamentum flavum have been found ossified, sometimes partially, sometimes completely. In excising the ossified ligamentum flavum, one should keep in mind that the dura is apt to be adherent to it and is, therefore, easily punctured. A leak of spinal fluid is in itself of relatively little consequence, but it does add another problem to the operative technique.

5. In introducing the elevator for the purpose of reflecting the periosteum from the anterior surface of the lamina, care must be exercised in order to avoid injury to the dura and spinal nerves. The inflammatory process which has resulted in the articular destruction is accompanied by periarticular adhesions and inelastic structures, not easily reflected.

6. The bone instruments should be of a delicate type,—they are intended to cut, not crush.

7. The possibility of overcorrection must be kept in mind. If the thoracic spine presents marked flexion, there is apt to be compensatory extension deformity of the cervical spine with motion in the occipitocervical joints only. In the presence of such deformities, overcorrection in the lumbar region makes it difficult for the patient to see his plate on the dining room table and to read without holding the book on a level with his head.

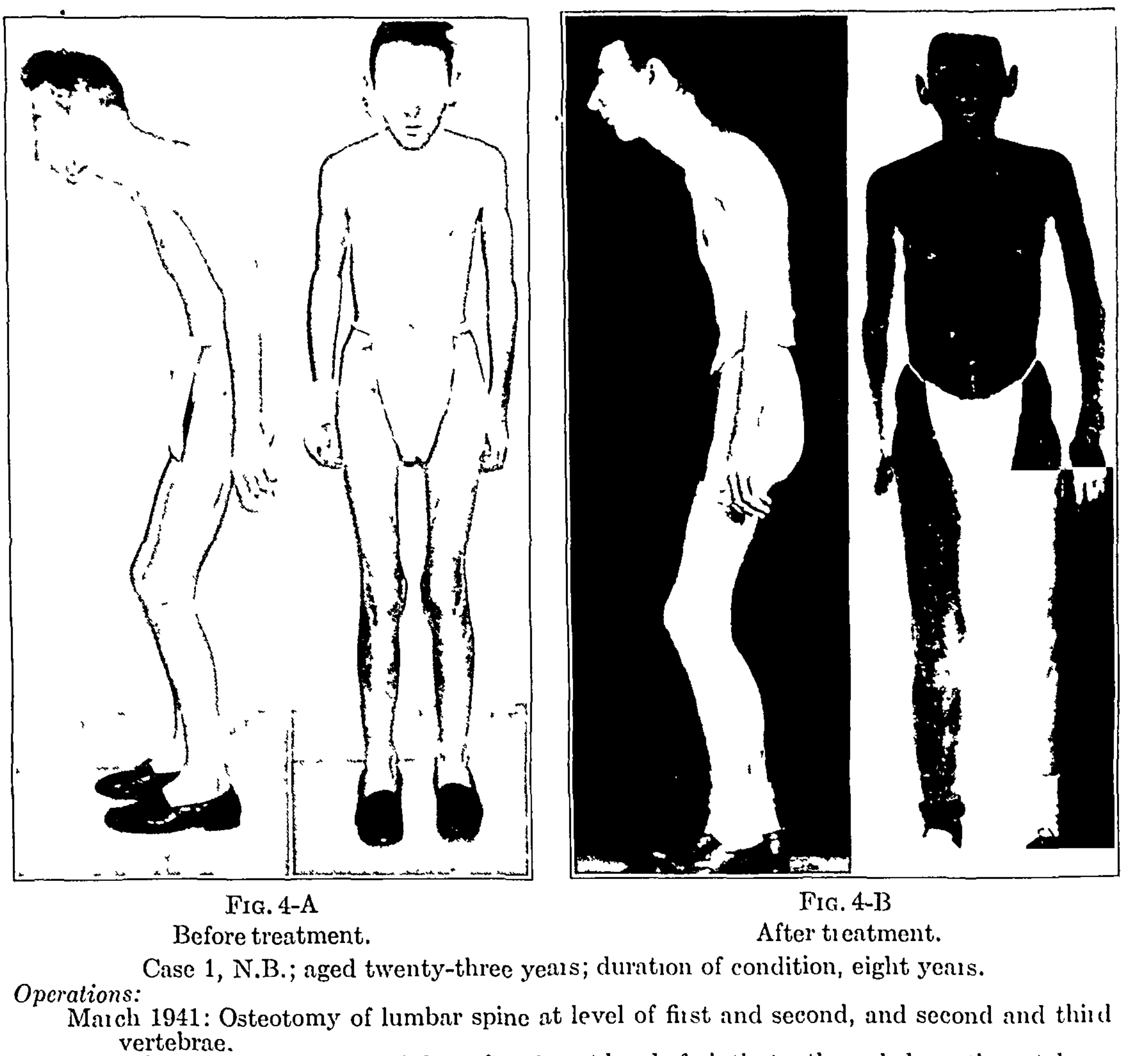


FIG. 4-A
Before treatment.

FIG. 4-B
After treatment.

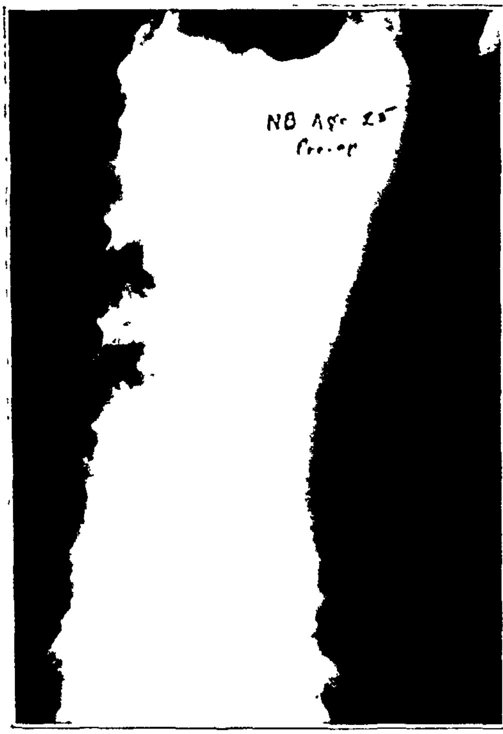
Case 1, N.B.; aged twenty-three years; duration of condition, eight years.

Operations:

March 1941: Osteotomy of lumbar spine at level of first and second, and second and third vertebrae.
December 1941: Osteotomy of thoracic spine at level of ninth, tenth, and eleventh vertebrae.
February 1943: Arthroplasty of left hip.
March 1943: Arthroplasty of right hip.

Present condition:

The patient is using crutches and wears a back brace part of the time. He tires easily, but says he has no pain, and can sit quite comfortably.



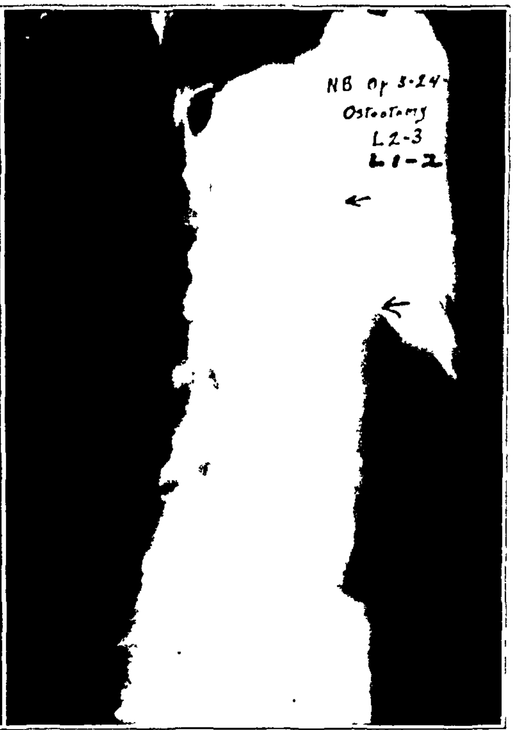


Fig. 4-C
Before treatment.

Fig. 4-D
After osteotomy.

The postoperative roentgenogram shows definite widening of intervertebral spaces between the first and second lumbar and the second and third lumbar.

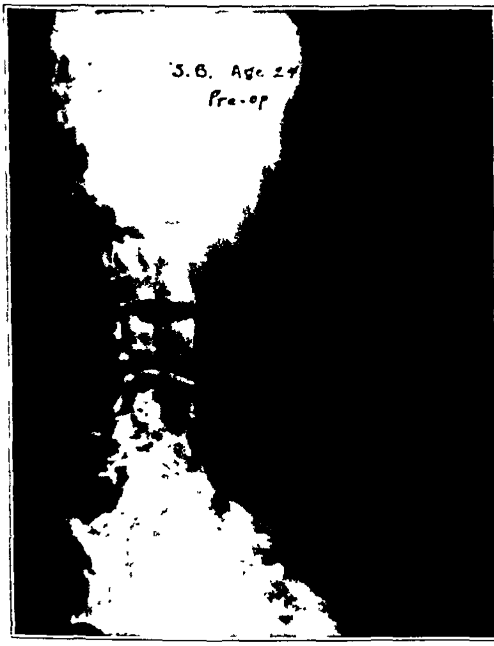


Fig. 5-A
Preoperative roentgenogram.

Fig. 5-B
After osteotomy.

Case 2, S.B.; aged twenty-four; duration of condition, six years.

Joints in order of involvement were right hip, spine, and left hip. Patient left college to have right hip fused for "tuberculosis". Postoperative immobilization in double plaster spica for one year resulted in ankylosis of spine in flexion, with both hips in flexion and abduction.

(*See page 8.*)

FIG. 5-A and FIG. 5-B (*continued*)

Operations:

June 1942: Arthroplasty of left hip. Bony ankylosis.
July 1942: Arthroplasty of right hip. Bony ankylosis.
August 1942: Osteotomy of lumbar spine and fusion with grafts from spinous processes.

Fig. 5-A: Preoperative roentgenogram. Fig. 5-B: After osteotomy of lumbar spine at level of third and fourth vertebrae.

Present condition:

The patient returned to college in October 1942. He is still using crutches at times, two canes most of the time. He is able to sit comfortably, and eight months ago resumed playing the piano.

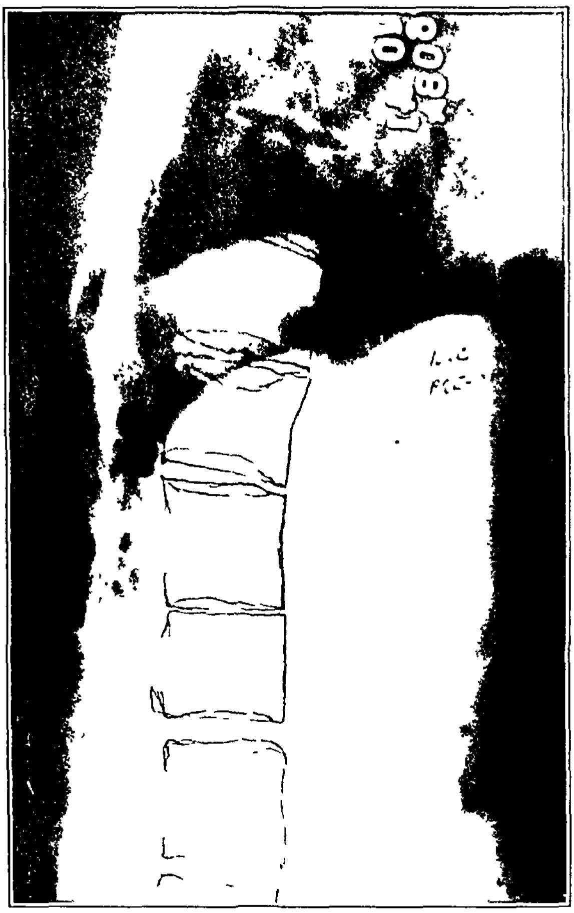


FIG. 6-A

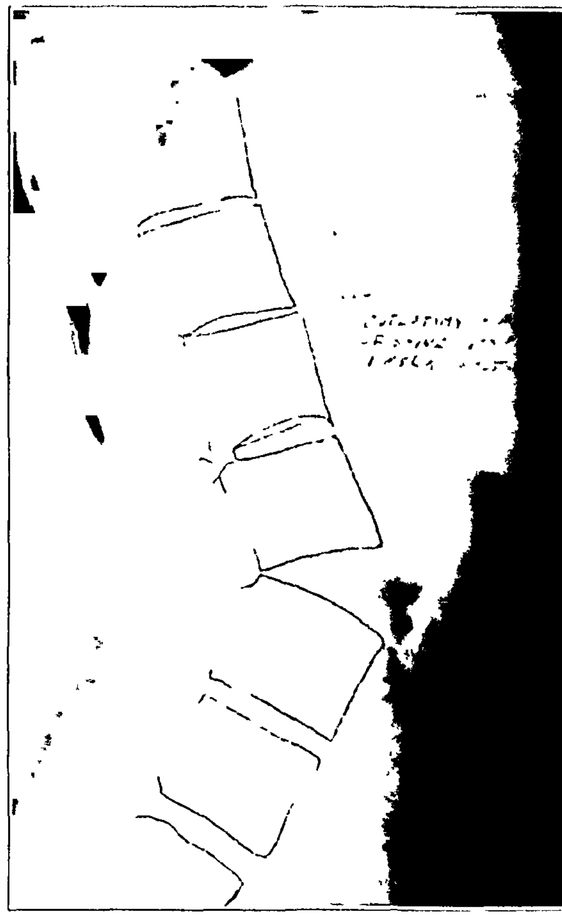


FIG. 6-B

Case 3, B.C.; aged thirty years; duration of disease, eleven years.

Joints in order of involvement were spine, hips, and jaws. Patient had been "frozen" in sitting position for seven years.

Operations:

February 1940: Arthroplasty of right hip.
April 1940: Arthroplasty of left hip.
September 1941: Gauze sponge removed from right iliac fossa. Operative wound healed *per primam,* but a small sinus developed one year later.
October 1941: Osteotomy of lumbar spine at level of second and third vertebrae.
November 1941: Fusion of osteotomized area.

Fig. 6-A: Roentgenogram before osteotomy. Fig. 6-B: Roentgenogram one week after operation showed marked correction at level of osteotomy, and consequently fusion was indicated.

Present condition:

The patient is using crutches or canes, occasionally only one cane. He is working eight hours a day, six or seven days a week, and says he has no pain. He goes fishing and hunting.

FIG. 7-A and FIG. 7-B (*See page 9.*)

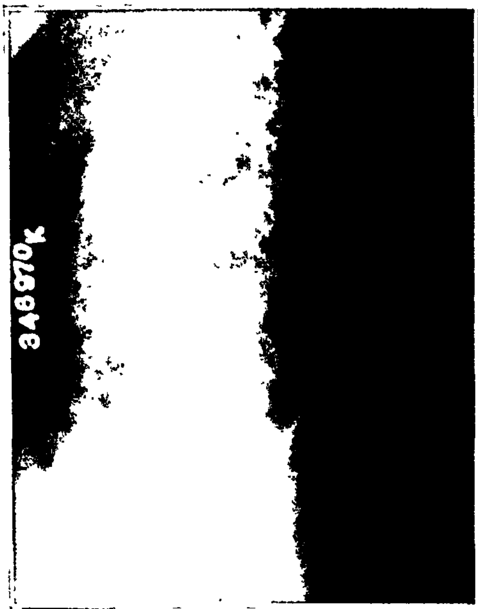
Case 4, R.F.; aged twenty-four years; duration of condition, two and one-half years.

Joints involved: Hips and spine.

Operations:

July 1942: Arthroplasty of left hip.
August 1942: Arthroplasty of right hip.
March 1943: Osteotomy of lumbar spine, and fusion.

Fig. 7-A: Preoperative roentgenogram. Fig. 7-B: After osteotomy of lumbar spine at level of the second and third and third and fourth intervertebral spaces, with fusion at the time of osteotomy.



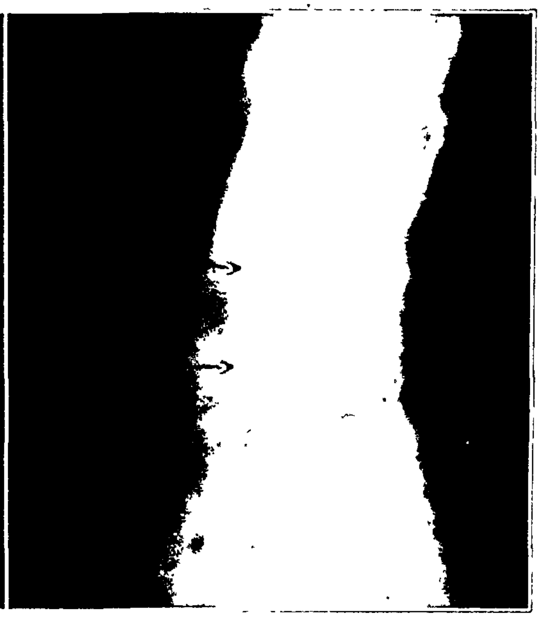
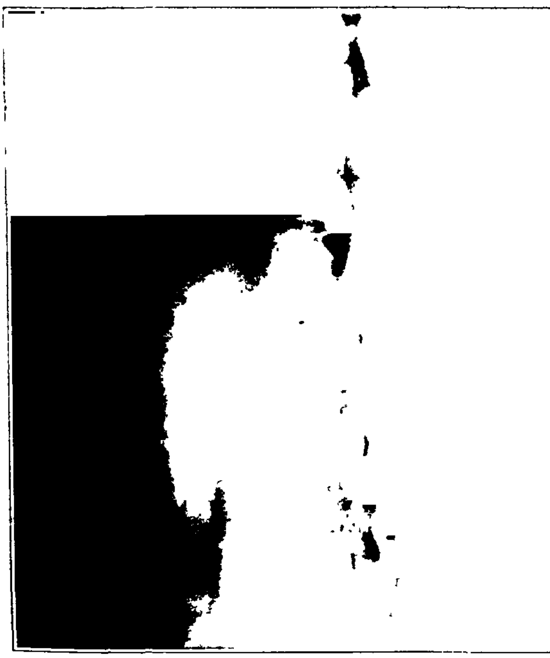


Fig. 7-A Fig. 7-B

Postoperative treatment: Plaster jacket was used for three months, followed by brace and exercises.
Present condition:
Patient uses crutches most of the time, occasionally two canes. He is studying drafting, and says he has no pain.



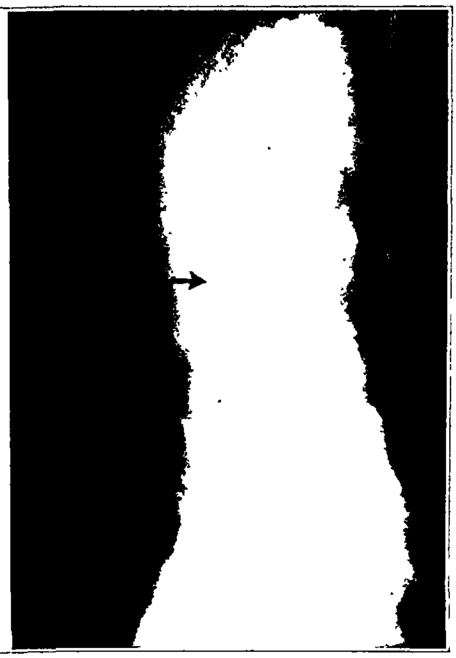


Fig. 8-A Fig. 8-B

Case 5, J.W.; aged thirty-five years; duration of condition, ten years.

Joints involved: Spine and hips.
Operations:
June 1938: Arthroplasty of left hip for bony ankylosis.
May 1941: Arthroplasty of right hip for fibrous ankylosis.
September 1943: Osteotomy of lumbar spine with fusion at the level of the third and fourth vertebrae.
Fig. 8-A: Before osteotomy. Fig. 8-B: After osteotomy of the lumbar spine with fusion.
Present condition:
Patient is able to run and ride a bicycle. He uses crutches at times, otherwise one or two canes.

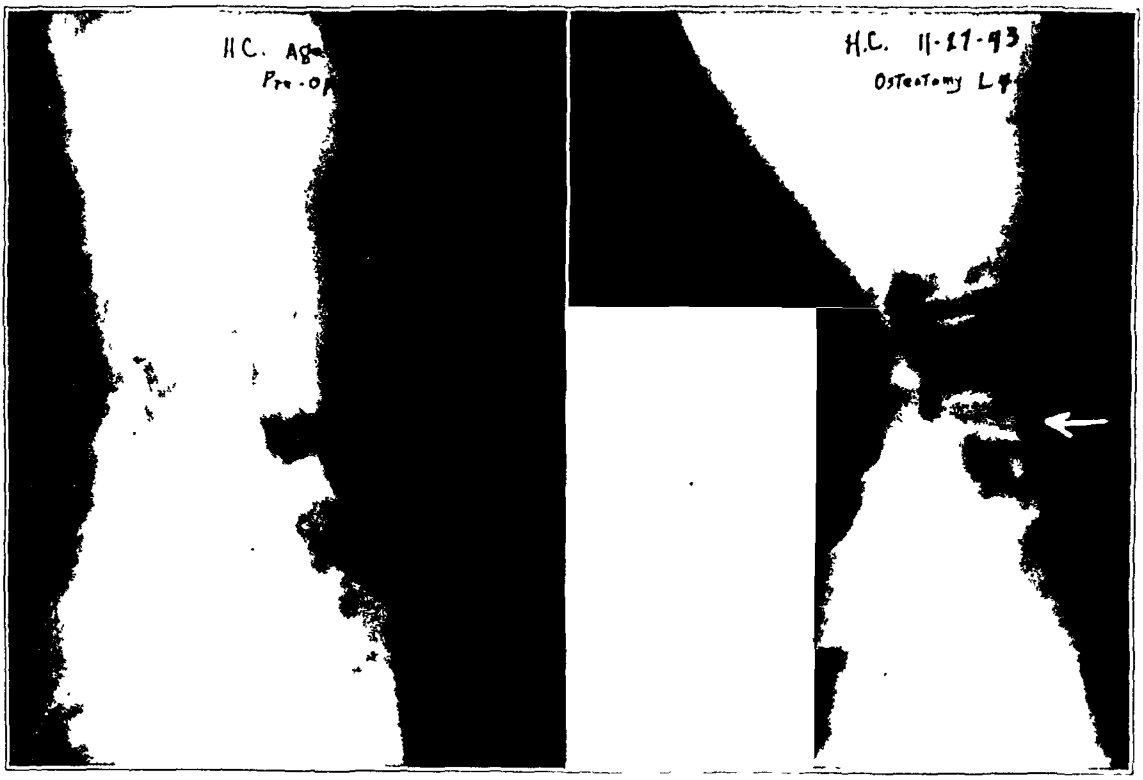


FIG. 9-A FIG. 9-B

Case 6, H.C.; aged thirty-six years; duration of condition, four years.

Joints involved: Hips and spine.

Operations:

September 1942: Arthroplasty of right hip for fibrous ankylosis.
October 1942: Arthroplasty of left hip for fibrous ankylosis.
November 1943: Osteotomy of lumbar spine with fusion at level of the fourth and fifth vertebrae.

Fig. 9-A: Preoperative roentgenogram. Fig. 9-B: Roentgenogram after osteotomy of the lumbar spine with fusion.

Present condition:

Patient is able to navigate about the house without crutches or canes, but does have occasional discomfort.

CONCLUSIONS

1. Surgical intervention in rheumatoid arthritis should be undertaken early, before secondary deformities develop.
2. Flexion deformity of the spine frequently results from delayed surgical treatment of the hips.
3. Such flexion deformity may be sufficiently severe to demand surgical correction.
4. Osteotomy of the spine, performed in a small series of six cases, has yielded satisfactory results.

1. SMITH-PETERSEN, M. N.; AUFRANC, OTTO E.; AND LARSON, CARROLL B.: Useful Surgical Procedures for Rheumatoid Arthritis Involving Joints of the Upper Extremity. Arch. Surg., XLVI, 764, 1943.

DISCUSSION

DR. GEORGE E. BENNETT, BALTIMORE, MARYLAND: Many years ago I had the honor of opening the discussion of a paper by Dr. Smith-Petersen—his first paper on the introduction of the Smith-Petersen nail. That was a subject I could talk on with perfect freedom, because I had had a great deal of experience with the operative reduction of fractures of the neck of the femur. Later, I had the honor and privilege of discussing his paper on the use of the vitallium cup for arthroplasty of the hip. That was also a subject about which I could talk from experience. Today I am confronted with opening the discussion on an operation on which I have had absolutely no experience. I can only say that this is an operation designed by a man who is one of the master-surgeons of his generation. I can see that it has its place. I know none of the older men are going to do this operation, unless they do a little work on the cadaver. As Dr. Smith-Petersen said, this operation should be reserved for the cases in which all conservative treatment has failed. I think again Dr.

Smith-Petersen has presented an operation developed by a genuine master-surgeon. Unless you are a master-surgeon, do not try it!

Dr. H. R. McCarroll, St. Louis, Missouri: This is an operative procedure I have never done, I have never seen, and, until about one month ago, I had never heard of. Any discussion by me must, therefore, be entirely theoretical.

First, there can be no objection to any procedure, regardless of how technically difficult it may be, which offers the unfortunate patient with a flexion deformity of the spine from Marie-Strümpell disease some hope of being able to look the world in the face once more. There are three points, however, which should, I think, be taken into consideration:

(1) The question as to whether or not these deformities should be fairly complete before surgery is done. If they are still in the formative stage, the deformity may recur. This in turn prompts the question of whether or not enough motion remains in the intervertebral spaces to allow correction of the deformity, if bone already bridges the interspaces along the anterior longitudinal ligament;

(2) The prospect of a surgical correction for the deformity should not prevent us from making every attempt to prevent the flexion deformity from developing. During the early stages of the disease, adequate conservative measures will accomplish this in some patients;

(3) This operation is not one to be undertaken by an amateur. Many of us have attempted exploration of a spine for a possible disc lesion after a previous spinal fusion. The technical difficulties encountered in the two operations are essentially the same. Such an exploration is one of the most difficult of all orthopaedic operations and should never be considered lightly.

Dr. M. N. Smith-Petersen, Boston, Massachusetts (closing): I have been very fortunate in having Dr. Bennett discuss all my first presentations of what I have considered new procedures. He discussed one procedure which he did not mention,—namely, that of acetabuloplasty. In his discussion he warned me that this procedure was not going to turn out as well as I expected; he was right. Evaluating the results of this operation, five years after I operated on the first case, I found that only 50 per cent. of the cases were satisfactory to the patient and to the surgeon. Since the advent of mold arthroplasty, we rarely do acetabuloplasties.

I want to thank Dr. Bennett for his encouraging discussion.

Dr. McCarroll asked three questions: The first was about the deformity being fixed before surgery is done. The operation is not undertaken until conservative measures have failed; it is performed in the lumbar region at levels showing a minimum of bony bridging. Such bony bridging may be expected to yield after osteotomies of the articular facets.

The second point that Dr. McCarroll raised is that of prevention of flexion deformity. This point can not be overemphasized, but, in spite of conscientious efforts in this direction, flexion deformities will occur every so often.

Finally, Dr. McCarroll points out the technical difficulties of the operation. I have emphasized this point in my paper, and Dr. Bennett has also referred to it. The operation is a difficult one and should never be undertaken lightly.

I want to thank Dr. McCarroll for his thoughtful discussion.

OSTEOCHONDRITIS DISSECANS OF THE SUPRATROCHLEAR SEPTUM

BY H. S. MORTON, SURGEON COMMANDER,
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Loose bodies in the elbow joint have not been previously classified and distinguished from accessory bones in this region. The nomenclature of abnormalities at the lower end of the humerus and the upper end of the radius and ulna is confusing, and consequently a consideration of the various terms and their definition seems advisable. These conditions may be divided into four classes: congenital, developmental, traumatic, and degenerative.

1. In the congenital group there are two terms: "sesamum cubiti", which was coined by Pfitzner, when he described the sesamoid bones, and "patella cubiti", a name introduced by Keinböck, which may be defined as the counterpart of the kneecap in the elbow.

2. Under developmental abnormalities may be placed the accessory bones in association with the olecranon process. The variations of the upper end of this process, as seen in the lateral views of the elbow, are numerous; the process may have near it a single rounded nodule, or there may be one or two small isolated bones just proximal to the upper end. Again, the upper end may be separate, in one large piece. These variations are almost normal findings, and they are thought to be accessory bones, formed from a secondary center of ossification, which have failed to unite with the main mass of bone. They are usually bilateral and may be associated with other comparable developmental anomalies. The first case reported in English, was published in 1942 by O'Donoghue and Sell. The lower end of the humerus may have discrete medial or lateral epicondyles.

3. The traumatic group is the largest. Separation of epiphyses includes the olecranon epiphysis, the upper epiphysis of the radius, as well as the lower end of the humerus, especially the medial epicondyle, which may be displaced by trauma, and thus may become a loose body in the elbow joint. The capitellum (capitulum humeri) and the lateral epicondyle may be similarly displaced into the joint. Fractures around the elbow joint may produce loose bodies. Osteochondritis may occur in the capitellum, the head of the radius, and also in the supratrochlear septum.

Pathological fractures in this region may lead to loose-body formation.

4. This group includes those cases in which degeneration is the dominant feature, but the degenerative changes do not lead to the formation of loose bodies except in association with trauma. In arthritis, usually hypertrophic, fracture of an osteophyte may produce a loose body. Avascular necrosis originates with trauma, but progresses because of interruption of the blood supply. Traumatic ossification results from a lifting up of the periosteum by trauma, followed by a hematoma and the degenerative change of calcification. With this is associated myositis ossificans. Degenerative ossification, such as osteochondromatosis, occurs in the villi and may lead to multiple loose bodies.

OSTEOCHONDRITIS DISSECANS

It is now proposed to present osteochondritis dissecans arising from a situation at the lower end of the humerus, a specific lesion not previously described.

The supratrochlear septum, when present, is a thin lamina of bone, separating the coronoid from the olecranon fossa and varying in thickness from 0.5 millimeters to one centimeter. The relationship of the synovial membrane to the septum is important. Anteriorly, the coronoid fossa is entirely within the elbow joint; while posteriorly, the synovial reflection passes across the upper portion of the floor of the olecranon fossa, so that only the lower half or two thirds lies within the elbow joint.

According to Hirsh, the septum is always present until the age of seven years, after which the bony plate occasionally becomes absorbed to form the supratrochlear foramen. This foramen is of great interest to anthropologists, who claim it as one of the points in establishing the close relationship between man and the lower animals. Hirsh quotes examinations by Martin which revealed the presence of the supratrochlear foramen in 58 per cent. of Arkansas Indians studied, and in 21.7 per cent. of African Negroes; but showed the proportion to be only 4.2 per cent. in white Americans. The same authority states that the supratrochlear foramen is consistently more common in the female by 38 to 10 per cent., and on the left side by 25 to 5 per cent., depending upon the race examined.

When the elbow is fully flexed, the coronoid process of the ulna fits into the coronoid fossa of the humerus, while in full extension the olecranon process impinges on the floor of the olecranon fossa. In the extremes of movement of this joint, there is apt to be repeated trauma to the septum, which may lead to osteochondritis dissecans.

Osteochondritis dissecans, first described by Koenig in 1889, is a non-infectious aseptic necrosis of a segment of subchondral bone, affecting principally the long bones of the extremities, and resulting in an osteocartilaginous sequestrum, which may lie as a free body in the joint. The necrosis appears to be due to interference with the vascular supply; trauma seems to be the chief etiological agent. The sequestrated fragment is covered with intact cartilage, and the subchondral necrotic bone is separated from the normal bone by a bloodless fibrous-tissue bed. The microscopic picture is one of necrosis with low-grade, productive, aseptic inflammation. Foreign-body giant cells are present. Roentgenographic examination is recognized as the principal method of diagnosis.

These observations are based on six cases, of which five have been confirmed by pathological examination. As far as we are aware, these are the first published cases of osteochondritis dissecans in the supratrochlear septum.

CASE REPORTS

CASE 1. R. J. W., thirty-two years of age, was a carpenter before joining the Navy. Fifteen years ago he had first noticed a pain like a sharp stab in the right elbow, with no radiation. He had had a number of attacks which lasted from one day to two weeks, intervals between attacks varied from two weeks to six months. The most recent attack had been in June 1943, and had lasted one week. He had been playing baseball a few days before, and attributed the limitation of movement and pain to this excessive use. He also stated that, if he used his right arm in hammering too much, trouble almost invariably followed. He did not seek medical treatment, as the pain gradually subsided. While duck-hunting in 1932, he had received a gunshot wound of the left elbow. Many of the pellets were palpable, and more were seen on the roentgenogram.

Clinical examination revealed the maximum point of tenderness to be deep-seated and immediately above the tip of the olecranon process. The range of movement was 54 to 100 degrees on the right and 50 to 175 degrees on the left, with full pronation and supination.

Roentgenographic examination of both elbows showed a separate button of bone, measuring 1.5 centimeters in width and one centimeter in height, situated in the supratrochlear septum of the right elbow (Fig. 2-A). The ossicle was surrounded by a narrow but complete translucent zone, and the density of the bone appeared unaltered. There was no evidence of fragmentation. The lateral projection showed the ossicle, 0.8 centimeters in diameter, and undisplaced (Fig. 2-B). The adjacent bone structures looked normal.

The supratrochlear septum of the left elbow was perforate, producing the so-called supratrochlear foramen. An accessory ossicle was demonstrated just below the medial epicondyle. Numerous circular metallic densities, measuring three millimeters in diameter, and having the appearance of lead shot, were present throughout the soft tissue of the left elbow region.

The diagnosis was probable osteochondritis dissecans of the supratrochlear septum of the right humerus.

On July 12, he was admitted to the Hospital, at which time there was no localized pain in the right elbow. Two days later an operation was performed under local anaesthesia, the posterior approach being used through the tendon of the triceps. When the floor of the olecranon fossa was reached, the loose body could be palpated with the examining finger, but could not be removed until a small incision was made into the capsule of the joint. A loose body, two centimeters in diameter, was found lying on the floor of the olecranon fossa, partly inside the capsule of the joint, and partly embedded in the humerus. This body was lifted out with a pair of forceps, and the wound was closed in layers without drainage. The patient was discharged from the Hospital on July 16, 1943. Two weeks later, when the stitches were removed, he had complete movement of the elbow joint of 55 to 185 degrees. He has continued on duty ever since without symptoms.

The specimen removed consisted of a white calcified body, with a rather honeycombed surface partially covered with cartilage, and measuring 20 by 15 by 7 millimeters (Fig. 1). Microscopically, the calcified body was composed of a central area surrounded by necrotic bone, which in turn was surrounded by an irregular layer of cartilage, some of this being necrotic. There were also foci of calcification present. The surface was covered with hyaline cartilage and fibrous tissue, except in one area, where there was a niche which was surrounded by necrotic cartilage and bone (Fig. 2-C).

The pathological diagnosis was osteochondritis dissecans.

Roentgenographic examination of the right elbow, after removal of the described button of bone, revealed what appeared to be a supratrochlear foramen, quite similar to that on the opposite side.

CASE 2. E. P. M., twenty-four years of age, had been in the Navy for seven years as a gunner, and was serving in two Canadian destroyers at the time of their respective sinkings. He did not remember incurring any injury to his elbow, although after the loss of one of the ships he had been admitted to a hospital in Plymouth with concussion, and abrasions of his leg.

The first attack of pain in the right elbow, however, was in September 1939, and it began without aggravating circumstances. This lasted one week and gradually subsided. The estimated limitation of movement at that time was about 25 degrees. The second attack occurred in April 1943, and began after more than ordinary use. This lasted one week, during which time a roentgenogram was taken. After being under medical observation until September 6, 1943, he was admitted to the Hospital.

Roentgenographic examination of both elbows revealed an irregularly oval and circumscribed button of bone, located in the supratrochlear septum of the right humerus (Fig. 3-A). The ossicle measured 1.5 centimeters in width, one centimeter in height, and one centimeter in thickness. The lateral projection (Fig. 3-B) revealed that the ossicle had been displaced anteriorly, so that it lay in the coronoid fossa.

The left elbow revealed a somewhat thinned supratrochlear septum. The adjacent bone structures and joint surfaces looked normal, and there was no evidence of any intra-articular foreign body.

The tentative diagnosis was osteochondritis dissecans of the right humerus.

At operation, a lateral incision was made over the supracondylar ridge, and was deepened through the muscle layers to the anterior aspect of the supratrochlear septum, close to the bone. A loose body, completely detached from the floor of the supratrochlear septum, was found at the upper limit of the right elbow joint. The normal synovial membrane was incised, and the loose body was lifted out. No other fragments were visible or palpable. The synovial membrane was closed and the wound was sutured.

The pathological picture showed the specimen (Fig. 1) to consist of a hard, whitish body which measured 16 by 11 by 8 millimeters. One surface was smooth and the other surface was honeycombed. Microscopically, the specimen was partially covered by fibrous tissue and perichondrium, and was composed of hyaline cartilage, a portion of which contained foci of calcification. Other parts were necrotic (Fig. 3-D).

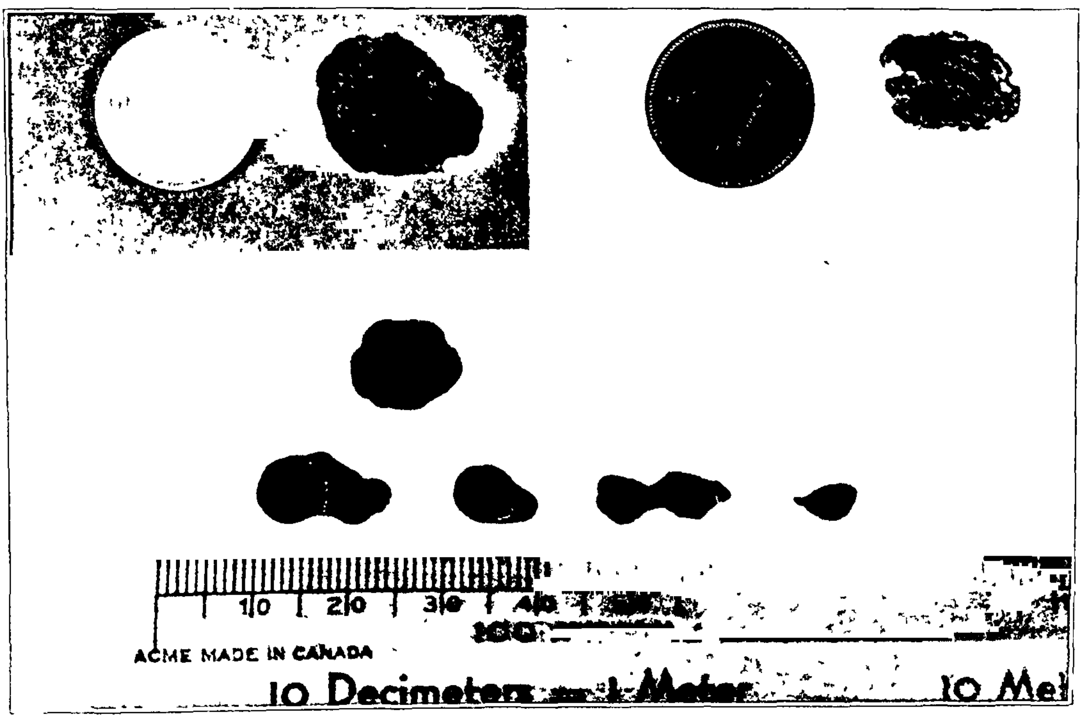

FIG. 1

Actual size of ossicles removed from four cases. The specimens are: top left, from Case 1; top right, from Case 2; center, from Case 6; and bottom, from Case 5.

The diagnosis was cartilaginous loose body (osteochondritis dissecans).

Three weeks after the operation, the wound had healed by first intention, and the patient had full flexion and 170 degrees of extension. When seen two weeks later, he was found to have regained full movement of the elbow joint, and was returned to full duty. He has remained well ever since.

Roentgenographic examination of the right elbow after removal of the ossicle revealed a thin supratrochlear septum, centrally situated, which was bordered by bone of increased density (Fig. 3-C).

CASE 3. L. L., twenty-one years of age, in May 1943, noticed pain in the left elbow which lasted two days, with limitation of movement. He had had a similar attack in February, when his left elbow had

FIG. 2-A

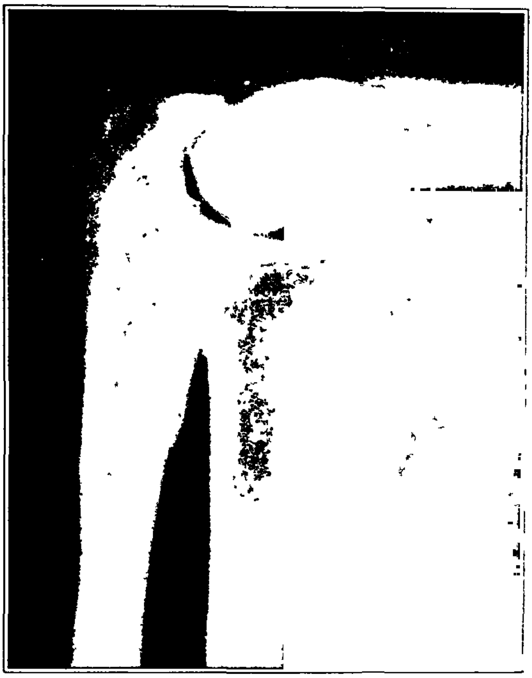

FIG. 2-B

Fig. 2-A: Case 1. A separate ossicle arising from the supratrochlear septum of the right humerus.
Fig. 2-B: The ossicle is undisplaced.

FIG. 2-C
Section of ossicle, magnified twelve times.

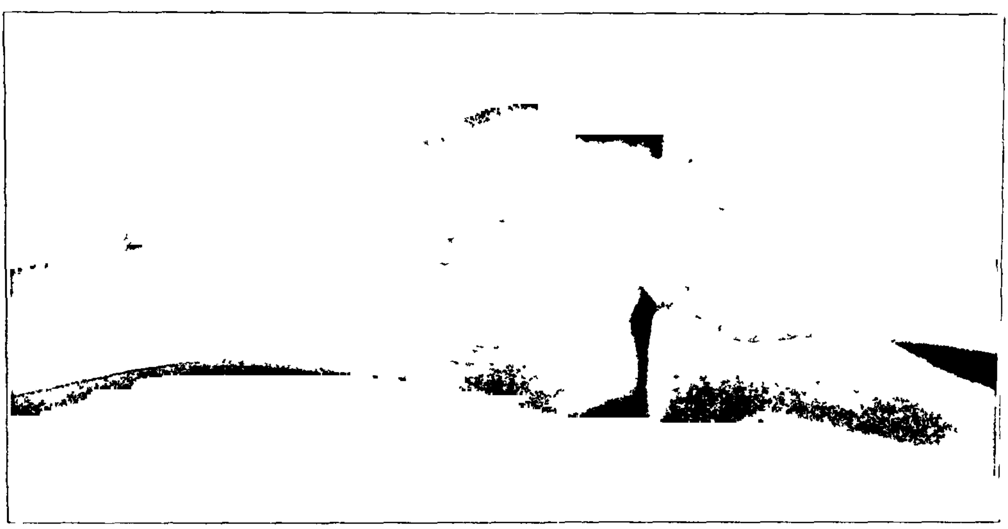

Fig. 3-A

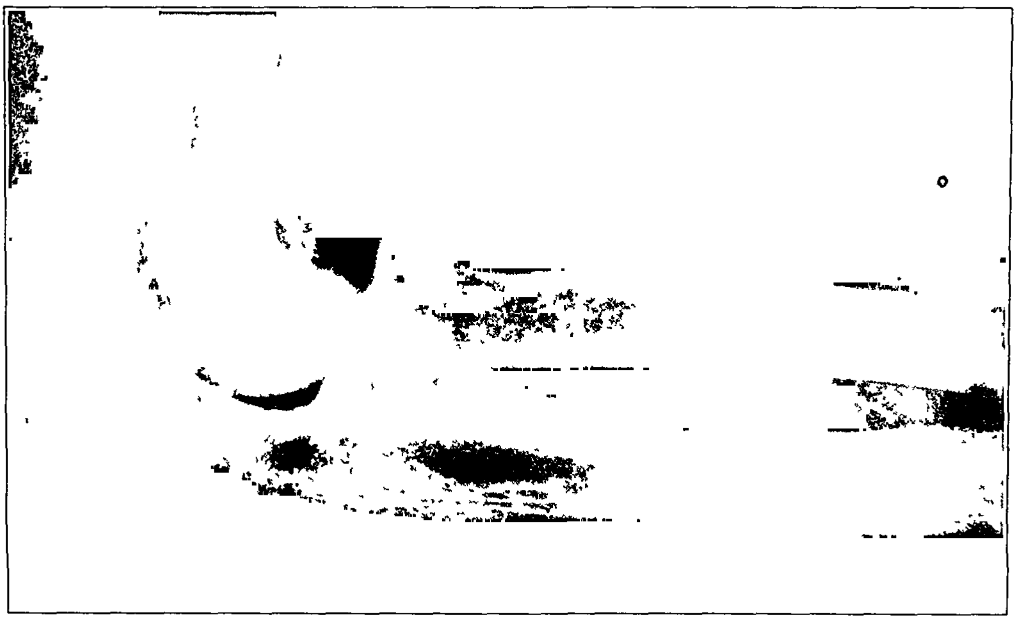

Fig. 3-B

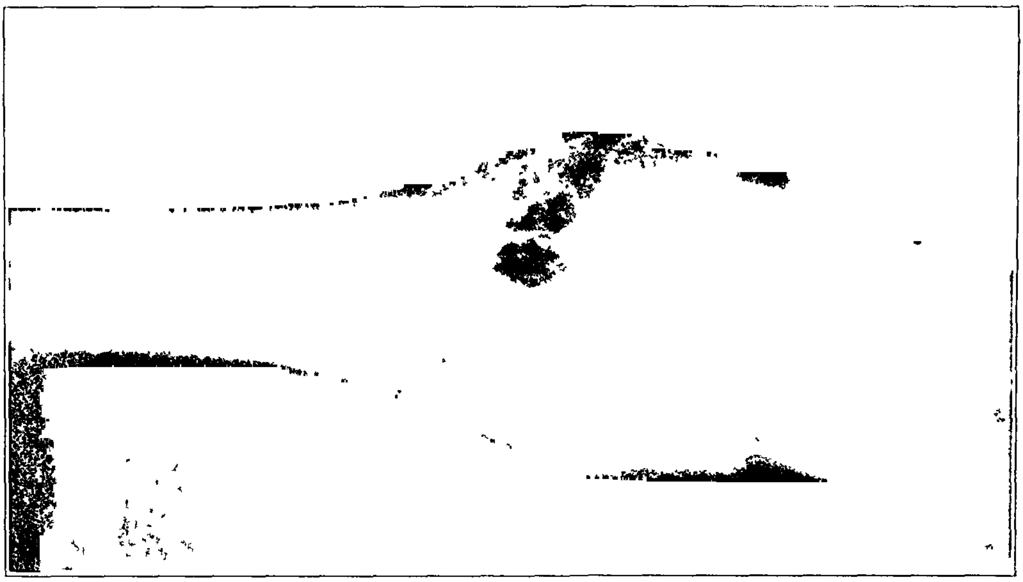

Fig. 3-C

Fig. 3-A: Case 2. A circumscribed ossicle situated in the supratrochlear septum of the right humerus.
Fig. 3-B: The lateral view shows the ossicle in the coronoid fossa.
Fig. 3-C: The right elbow after removal of ossicle.

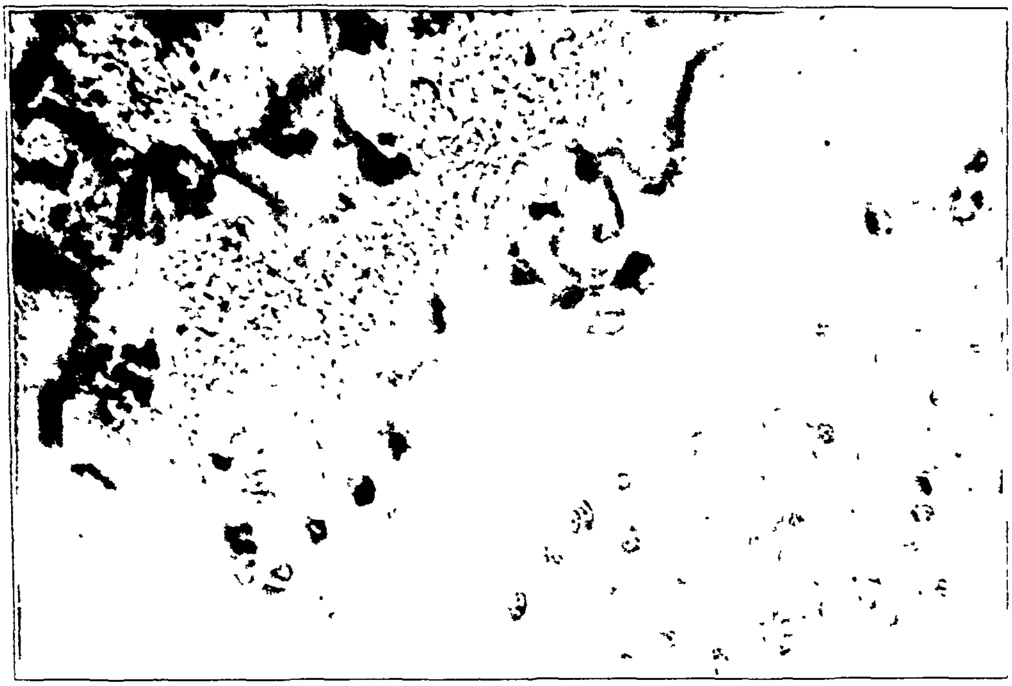

FIG. 3-D

Microscopic section of specimen under high power.

locked, and this had lasted four days. There was no history of injury. The pain did not radiate; it was centralized just above the olecranon process.

Examination showed that he had a range of movement from 70 to 160 degrees in the left arm, while the range was from 50 to 180 degrees in the right arm. There was 75 per cent. of pronation and supination of the left forearm. His work in the Navy as a stoker was comparatively strenuous, and before joining the Navy he had been a laborer. The movement of the elbow is illustrated by photographs (Figs. 4-A and 4-B), taken during the second attack, and one week later, respectively.

Roentgenographic examination of the left elbow in the frontal projection revealed a circular button of bone with normal density, bordered by a translucent zone, approximately one centimeter in depth (Fig. 4-C). There was no displacement (Fig. 4-D). The button showed no evidence of destruction, bone production, or fragmentation. There was no indication of an intra-articular foreign body, and the adjacent bone structures and joint surfaces appeared normal.

The right elbow revealed an extremely thin supratrochlear septum (Fig. 4-E). In other respects the bone structures and adjacent joint surface looked normal.

The diagnosis was osteochondritis dissecans of the supratrochlear septum of the left humerus.

Excision of the loose body was recommended, but has not yet been done, since the patient is now serving at sea.

CASE 4. T. K., thirty years of age, had bumped his elbow, four years previously, on a large aluminum cathode used in zinc plating. The elbow was sore for one week, and roentgenograms were taken (Figs. 5-A and 5-B). In September 1942, when throwing onto his shoulder a dunnage bag, weighing about 100 pounds, his left elbow locked. By manipulation of the affected arm, it was unlocked.

On February 17, 1943, an operation was performed to remove a loose body in the left elbow joint.

The diagnosis was osteochondritis of the capitellum.

After the operation, the arm was very painful for about a week. Full movement was never recovered, but there was no recurrence of pain or locking.

In December 1943, while reviewing the roentgenograms of the elbow joint to determine the presence of osteochondritis dissecans of the supratrochlear septum previously missed, the patient's roentgenograms were found to be positive.

Films were made of the left elbow in various directions. There was no sign of recent fracture. There was, however, evidence of a loose body of bony density, measuring approximately one centimeter in its widest diameter, in the region of the lateral condyle of the humerus. The articular surface of the condyle was irregular; the joint spacing was normal.

The appearance was that of a healed osteochondritis with formation of a loose body (Figs. 5-C and 5-D).

On December 24, an operation was performed and a loose ossicle was removed from the left supratrochlear fossa. Under general anaesthesia, a three-inch curved incision was made in the antecubital fossa, lateral to the biceps tendon, and was deepened to the elbow joint. The nerve was retracted laterally and the joint capsule was opened. The loose body lay immediately below the incision. It was grasped with forceps and was easily removed. The joint capsule was closed, and the wound was sutured in layers.

The specimen included a number of small fragments of bone and cartilage which together measured 20 by 15 by 6 millimeters. The specimen was composed partially of pieces of hyaline cartilage which was fibrillated in some areas (Fig. 5-E). Other portions of normal-appearing hyaline cartilage were attached to simple lamellar bone, the cells of which stained well.

The pathological report showed that the specimen included (1) fragments of an osteocartilaginous body and (2) normal bone from the supratrochlear septum.

Postoperative roentgenographic examination was made of the left elbow and compared with the previous series. The loose body situated in the coronoid fossa had been removed, except for a small fragment of calcification remaining in this region. Also a minute fragment, connected to the lateral condyle of the humerus, not previously demonstrated, was identified. The portion of this condyle, previously described as the focus of the osteochondritis, had been removed.

Six weeks later the patient had no pain, but some tenderness was present at the lower end of the wound. The range of movement was from 184 to 50 degrees on the right, and from 167 to 56 degrees on the left, with full pronation and supination. Slight weakness was seen in extension of the thumb and fingers, with moderate loss of ulnar deviation. This was attributed to temporary compression of the radial nerve by retraction during the operation. He was returned to full duty but continued to receive physiotherapy and remained under medical observation. On March 24, 1944, he had full pronation and supination with flexion from 176 to 55 degrees, while the power of the left hand was normal.

Case 5. W. M., twenty years of age, had first noticed pain in the left elbow in April 1943, while working in a railway freight department. He found that he could not lift a 150-pound carton because of pain in the right elbow, which he could not localize. Full extension or flexion of the elbow was impossible. He consulted the Medical Officer who advised bathing the affected joint in hot water.

For the first six months in the Navy, the patient was driving an ambulance and had no difficulty because he did not lift weights. One month before admission, he was helping to move a heavy lathe, when he felt a sharp pain in the elbow. When he stopped pushing, the pain stopped. On November 29, while carrying a carton of beer, he was forced to drop it, because of the pain in the left elbow. This discomfort lasted a week.

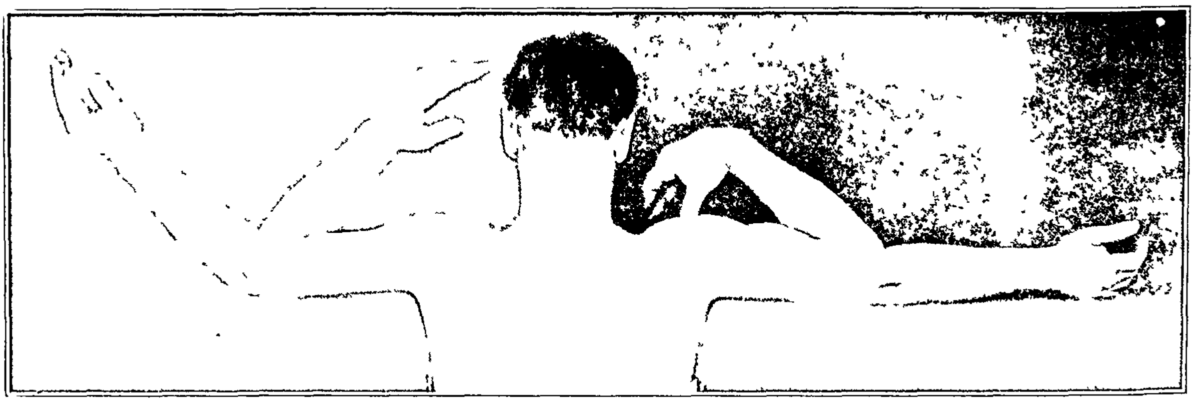

Fig. 4-A
Case 3. The range of movement of the left elbow during an attack.

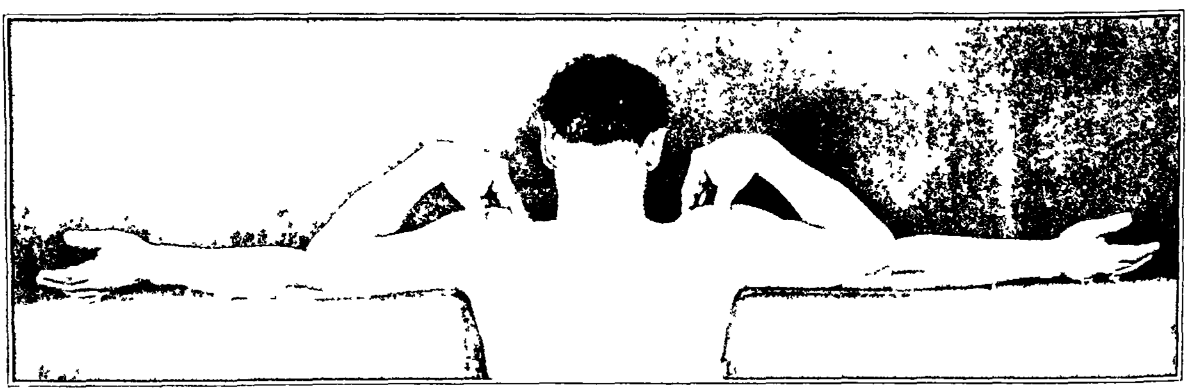

Fig. 4-B
Showing the range of movement one week later.

Fig. 4-C

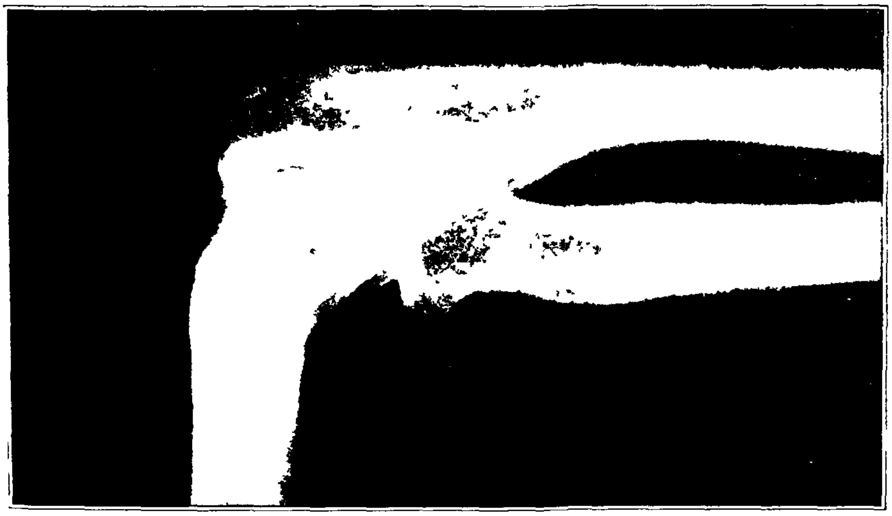

Fig. 4-D

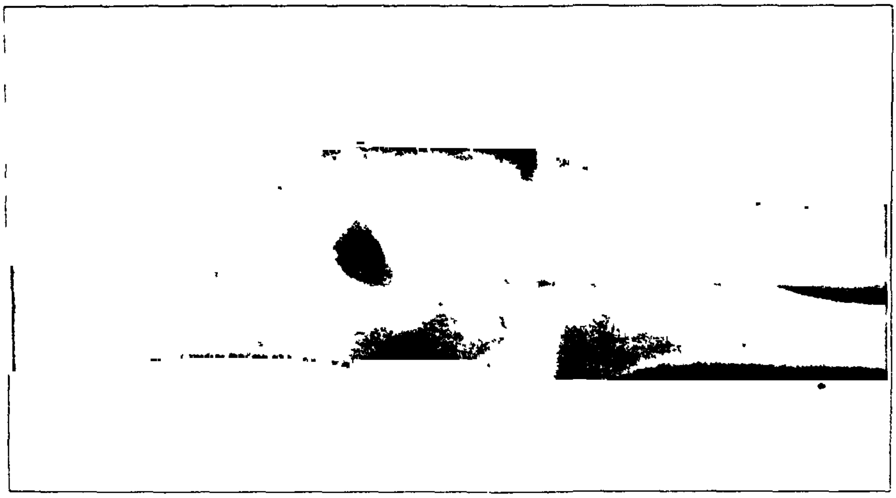

Fig. 4-E

Fig. 4-C: The ossicle in the supratrochlear septum of the left humerus.
Fig. 4-D: Showing the ossicle undisplaced.
Fig. 4-E: The right elbow, with very thin septum

Clinical examination, January 5, 1944, revealed slight tenderness in the antecubital fossa in the upper inner quadrant. Movement of the left elbow was from 157 to 50 degrees, and of the right elbow from 175 to 45 degrees. The diagnosis was osteochondritis dissecans of the supratrochlear septum.

Roentgenographic examination was made of both elbows. A separate ossicle, lying in the coronoid fossa of the left elbow, measured approximately seven millimeters in diameter in the frontal projection, and three millimeters in diameter in the lateral view. This seemed to be rising from the supratrochlear septum of the humerus. The right elbow joint and adjacent bone structures seemed normal. The supratrochlear septum appeared to be of average thickness.

An incision was made in the antecubital fossa to the lateral side of the biceps tendon, was deepened

Fig. 5 A

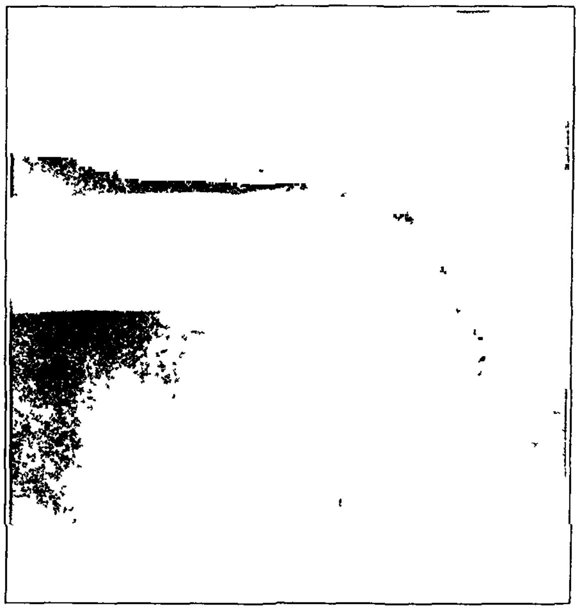

Fig. 5-B

Fig. 5-A: Case 4. Anteroposterior view of the left elbow, showing ossicle in supratrochlear septum.
Fig. 5-B: Lateral projection, showing ossicle in coronoid fossa.

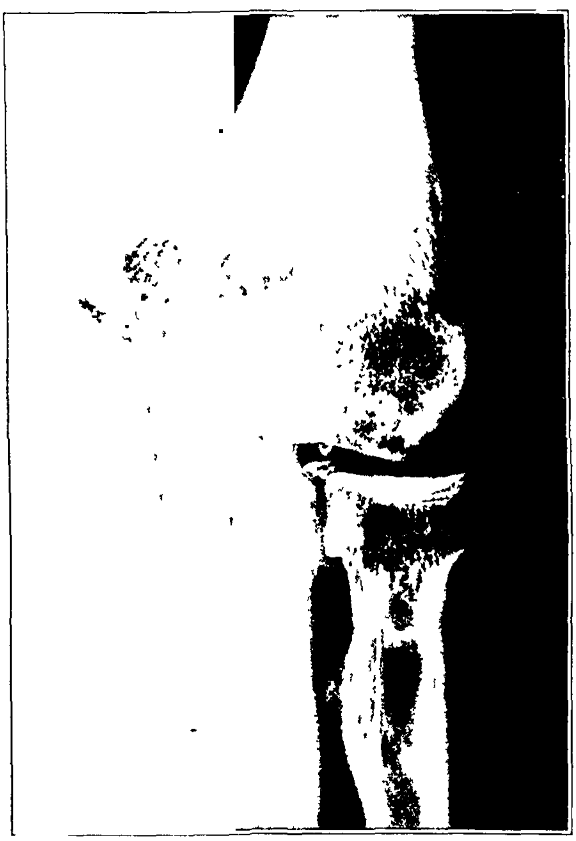

Fig. 5-C

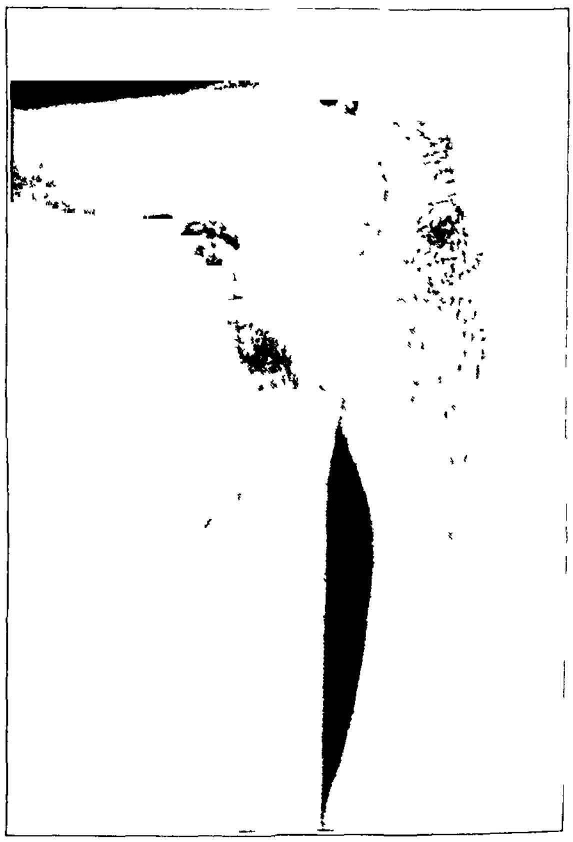

Fig. 5-D

Four years later, anteroposterior and lateral views.

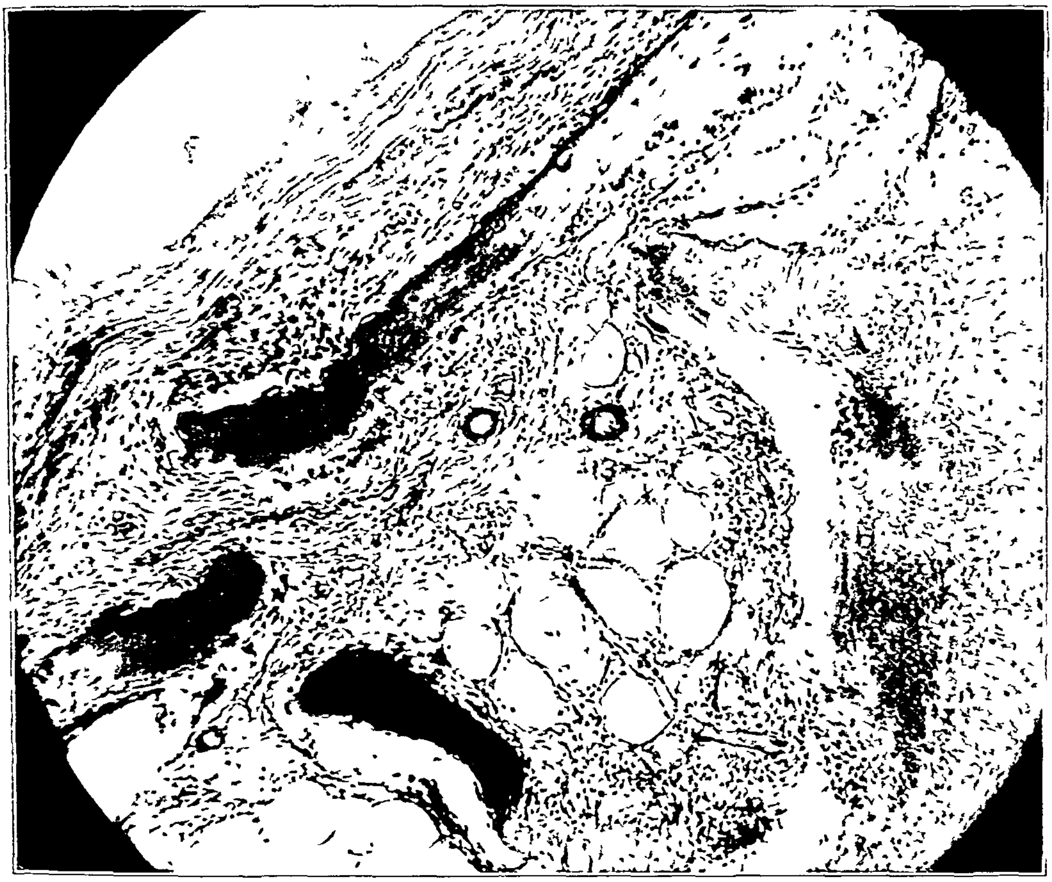

FIG. 5-E
Photomicrograph of specimen.

through the brachialis muscle, and the joint was exposed. The elbow was flexed, and the synovial membrane, found to be thickened anteriorly, was incised. A piece was removed from the coronoid fossa, and a specimen of the floor of the fossa was taken for section. The wound was closed in layers without drainage.

The specimen consisted of four hard, whitish bodies with smooth surfaces, the largest of which measured 16 by 7 by 4 millimeters, and the smallest approximately 6 by 5 by 4 millimeters. There was also a small piece of soft, grayish tissue (Fig. 1). Microscopically, the whitish bodies were composed chiefly of hyaline cartilage, throughout which were small or larger irregular areas of bone, some necrotic.

The membrane was composed of loose, fibrous, and adipose tissue, the surface of which was thrown up into short, blunt villi covered with mesothelium and infiltrated to a mild degree by lymphocytes.

The pathological report showed (1) loose osteochondromatous bodies (probably secondary osteochondritis dissecans) and (2) normal synovial membrane.

A postoperative roentgenographic examination of the left elbow region demonstrated that the separate ossicle in the coronoid fossa of the left elbow had been removed. The coronoid fossa appeared to be clear, with some possible roughening at its base.

Two weeks after the operation, the range of movement was 175 to 45 degrees on the right, and 165 to 45 degrees on the left. The patient complained of a tight feeling on lifting the edge of a desk but had no other symptoms. He was returned to duty and has been seen at regular intervals with no complaints.

CASE 6. A. S. C., nineteen years of age, first noticed pain in the right elbow joint in February 1943, the day following a softball game. The pain lasted five or six days, and was localized in front of the elbow in the upper, outer portion. He also had difficulty in extending and bending the elbow, which persisted one and a half weeks. Treatment consisted of wearing a sling one week. No roentgenogram was taken.

On December 24, 1943, he noticed pain in the right elbow, which greatly increased during the next three days. Any lifting made the pain worse. On December 31, while helping to load a ship and while lifting a 100-pound container, he felt a sudden pain in the right elbow which prevented him from continuing his job. He could not bend his elbow or straighten it out fully.

Clinical examination revealed tenderness in the antecubital fossa, in the upper inner quadrant. The range of movement of the left elbow joint was from 60 to 162 degrees.

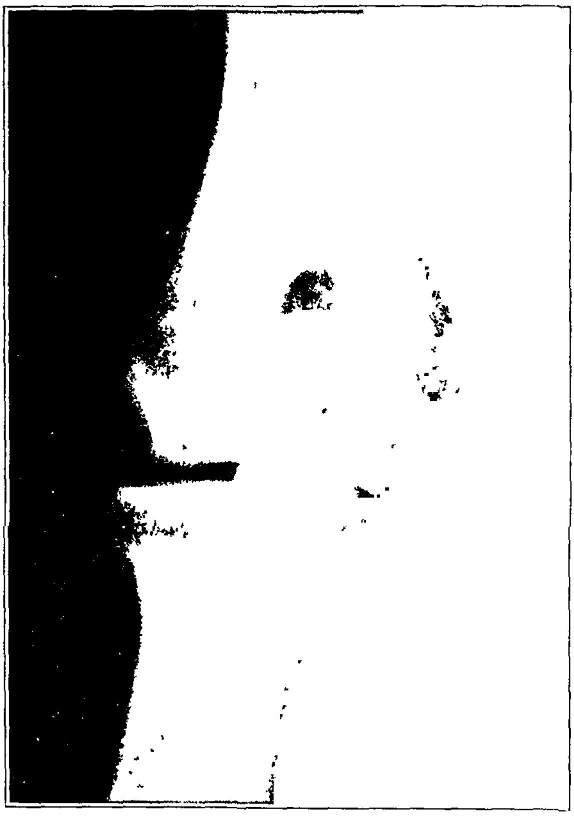

FIG. 6-A

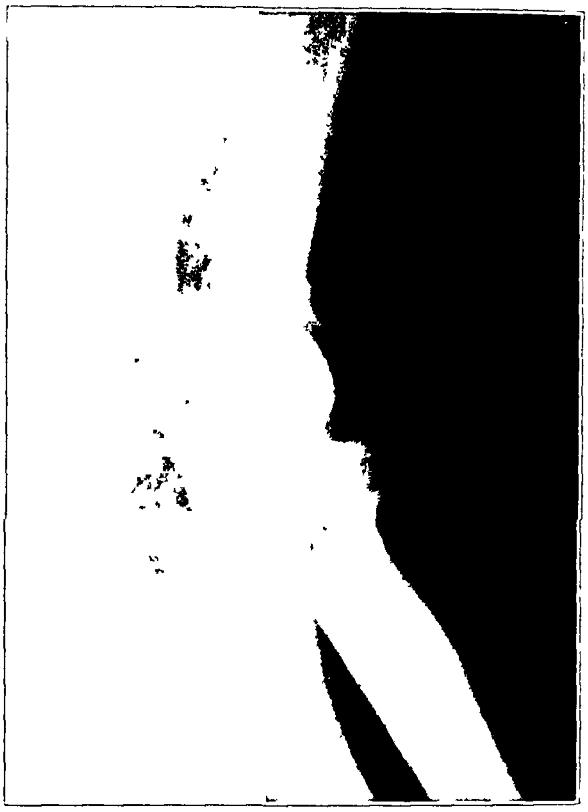

FIG. 6-B

Fig. 6-A: Case 6. Anteroposterior view of the right elbow, showing ossicle in supratrochlear septum and so-called bone island.

Fig. 6-B: Lateral view, showing ossicle in coronoid fossa.

A preoperative roentgenographic examination was made of the right elbow. A separate ossicle was demonstrated in the coronoid fossa of the lower end of the humerus, which had arisen from the supratrochlear septum, thereby creating a supratrochlear foramen. The ossicle appeared to be lying completely free from the adjacent bone surfaces; it measured seven millimeters in diameter. The density of the bone bordering the supratrochlear foramen was somewhat increased. An island of bone was present in the medial epicondyle. No further change was apparent. The findings were those of osteochondritis dissecans with complete separation (Figs. 6-A and 6-B).

Removal of the ossicle was done January 12, 1944. An incision was made lateral to the biceps tendon and was deepened until the joint was exposed. The elbow was slightly flexed and the synovial membrane was incised. The synovial membrane was normal, and one large ossicle was found in the coronoid fossa. This was lifted out and the floor of the fossa was curetted. It was found to be perforated. The wound was closed in layers without drainage.

The specimen consisted of a hard, whitish nodule which measured 12 by 10 by 8 millimeters (Fig. 1). There was also a small piece of membrane. Microscopically, the specimen was composed largely of hyaline cartilage, containing foci of necrosis and of calcification and ossification. The surface was partially covered by cellular fibrous tissue. The piece of membrane was composed of fibrovascular tissue, and one surface was thrown up into blunt projections, covered by a layer of flattened mesothelial cells.

The pathological report showed (1) osteochondromatous joint body (probably secondary to osteochondritis), and (2) normal synovial membrane.

Roentgenographic examination was made of the right elbow region and demonstrated that the separate ossicle, which was previously shown in the coronoid fossa of the lower end of the humerus, had been removed.

Two weeks later, the range of movement of the right elbow was 50 to 174 degrees. There was no pain.

On March 20, 1944, no evidence of tenderness was found and the scar was well healed. There was full range of movement of from 48 to 178 degrees. After two months of full duty, the patient said the arm did not bother him when lifting, bending, or in any ordinary use.

CLINICAL ASPECTS

The clinical characteristics of these cases include recurrent attacks of pain in the elbow joint, with localized tenderness above the tip of the olecranon process or in the upper part of the antecubital space, lateral to the biceps tendon, associated with limitation of movement both in flexion and in extension. Locking occurs only when the ossicle

becomes a loose body, and migrates into the joint. The attacks last from a day to a fortnight, and gradually subside. They are usually brought on by excessive use. At operation, the bony button can usually be lifted easily out of its bed. The choice of approach depends upon the position of the ossicle as revealed by the lateral roentgenogram, and may be either anterior or posterior.

The six cases all show the same lesion, which has been best observed in the frontal projection of the elbow. Here is seen, depending upon the degree of separation, a sharply demarcated, circular or oval button of bone, which, if undisplaced, possesses normal density; it is located in the intra-articular portion of the supratrochlear septum. The lateral projection demonstrates the thickness of the ossicle, and confirms its position. When separation takes place, partial or complete extrusion of the ossicle into the humero-ulnar joint may occur, either forward into the coronoid fossa, or backward into the olecranon fossa, thus producing a loose body in the joint.

LITERATURE

In the literature, six cases have been reported in which an ossicle was found in or near the supratrochlear septum. None of these, however, was described as osteochondritis dissecans. We do not wish to suggest a diagnosis for these cases, but would like to summarize them and discuss the differential diagnosis.

In 1927, Hirsh showed roentgenograms of the right elbow in a man fifty years of age with a small round ossicle of bone in the supratrochlear foramen, which he labelled "sesamum cubiti" after Pfitzner. In the same year, Grauer reported a bean-sized swelling in the right elbow of a male, twenty-six years of age. This he removed from the floor of the olecranon fossa, to which it was attached by firm-textured bands. One year later, Winckler, reporting in the same journal, presented two roentgenograms of the right elbow of a boy, fifteen years of age. At operation, a cartilaginous, bony ball, one centimeter in diameter, was removed from the floor of the olecranon fossa. Quoting Grauer and Hirsh, Winckler called it "sesamum cubiti".

In 1933, Atsatt published a report of a loose body of an unusual form and location found in the elbow joint. He described a spherical bony mass, half the size of a marble, in the supratrochlear region, and stated that removal was simple. The following year Kleinberg, writing on osteochondromatosis of the elbow, described the case of a male, forty years of age, and presented a roentgenogram of his right elbow. This showed, among several loose bodies of the joint, a circumscribed shadow in the olecranon fossa. The patient refused operation. This is an incidental finding in a case of osteochondromatosis, and is not ascribed to this condition. Burman, in 1941, presented a case of an "unusual body in the right elbow joint" in a male bartender, calling it "sesamum cubiti". This dime-shaped piece of bone, felt beneath the triceps, interfered with extension of the elbow. A roentgenogram showed a definite round shadow in the supratrochlear septum.

These are the six reported cases, of which four are called "sesamum cubiti", one, a loose body, and one, an associated finding in a case of osteochondromatosis.

Köhler, in commenting on Grauer's case, considers that, as the elbow on the other side was normal, this was either an accessory bone or some condition other than "sesamum cubiti". It is to be noted that Pfitzner's work on sesamoid bones and, incidentally, on "sesamum cubiti", was done prior to the discovery of the roentgen ray. Grauer in 1927 used the term, and since then, Hirsch, Winckler, and Burman have described similar cases and have likewise clung to the name without the expedient of microscopic investigation.

DISCUSSION

In all of our cases which came to operation, the histological findings were those of osteochondritis dissecans. There is nothing to indicate that the condition is anything but

a sequestrating lesion of the supratrochlear septum, without evidence of bone infection. The manifestations do not differ from those seen in osteochondritis dissecans in other sites. An accessory ossicle of the olecranon process may be confusing in the frontal view, as it is projected through the superimposed supratrochlear septum or foramen. The lateral view should show it clearly.

It is interesting to note the similarity in the roentgenographic appearance of the supratrochlear foramen and the picture after the removal of the ossicle of osteochondritis dissecans. The presence of a thin septum or foramen on the opposite side was seen in our cases; this precludes the development of osteochondritis dissecans, because only with repeated minor traumata to the thick septum can the lesion occur.

In a consideration of the relationship of osteochondritis dissecans in this site to the supratrochlear foramen, two theories present themselves. As the anthropological examinations have been carried out almost exclusively on the dried specimen, may it not be possible that a proportion of the foramina have been produced by osteochondritis dissecans and the separated ossicle has been lost? On the other hand, the resolution of the septum, which normally takes place after the age of seven years, may not proceed according to plan, and thus, in conjunction with trauma, may produce the separate ossicle.

Thus we conclude that a more precise terminology should be applied to loose bodies in the elbow joint, and that such loose bodies should be removed and subjected to microscopic examination. A larger series of cases with detailed information should help to elucidate the cause of osteochondritis dissecans.

NOTE: The authors are indebted to the late Dr. Gordon A. McCurdy, pathologist at the Royal Jubilee Hospital, Victoria, British Columbia, for his kindness in preparing the pathological reports and slides.

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Their thanks are also due the Photographic Department of the Royal Victoria Hospital, Montreal, and the Photographic Section of the Royal Canadian Navy for cooperation in preparing the illustrations.

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RETARDATION OF BONE GROWTH BY A WIRE LOOP *

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There are three methods available for length equalization of unequal lower extremities. The long bones of the shorter limb may be lengthened; portions of the bones of the longer limb may be resected; or the bone growth of the longer extremity may be arrested by destroying the epiphyseal cartilaginous plate. Each method has its advantages and disadvantages, varying with the individual underlying anatomical and mechanical factors that may be present. There is no satisfactory method of stimulating bone growth. It has been suggested from time to time that roentgenotherapy, sympathectomy, periosteal stripping, and direct irritation of the epiphyseal cartilaginous plate would produce length increase in a bone, but the results of these methods are variable, and, to date, of no practical value. If a successful method of growth stimulation were devised, it would supplant

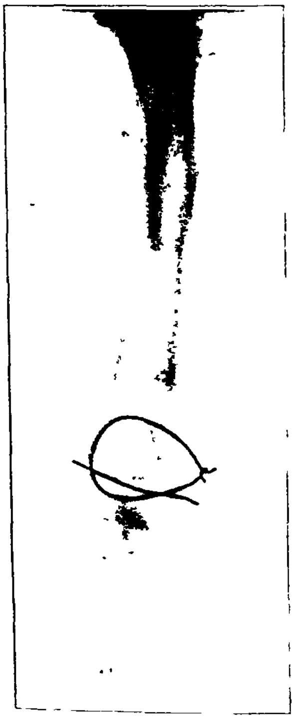


FIG. 1-A

Dog 3-W.B. Showing wires as originally inserted.

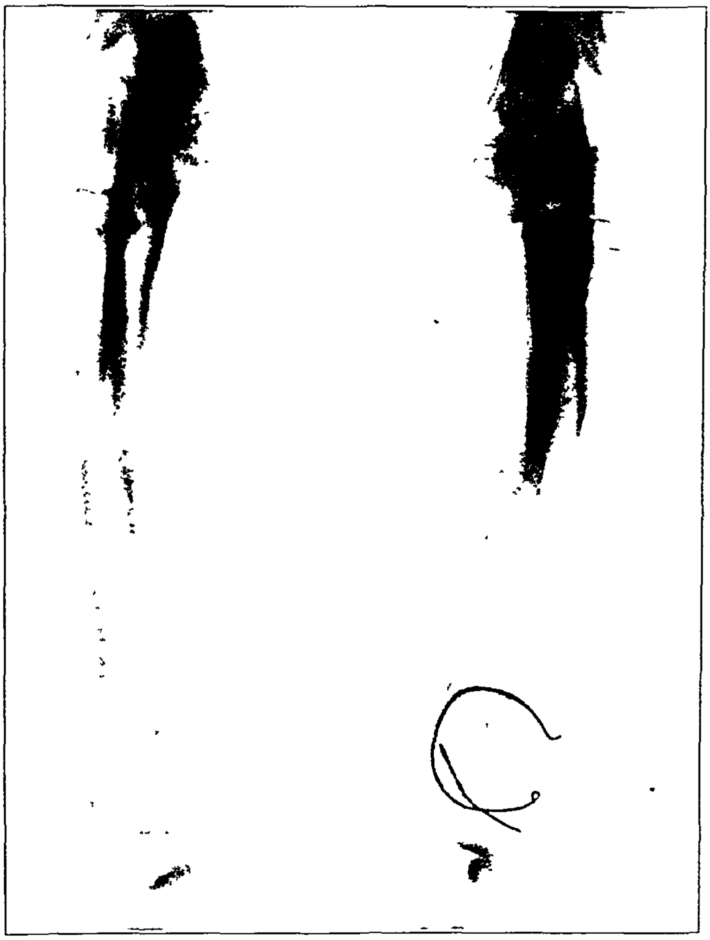


FIG. 1-B

Showing unfastened wire loop and partial restriction of length growth fifty-five days later.

* Read at the Annual Meeting of The American Orthopaedic Association, Hot Springs, Virginia, June 2, 1944.

to a considerable extent our present procedures for correcting inequality in the length of the lower limbs.

It was during a series of experiments, in which an endeavor was made to stimulate bone growth, that the observation was made which led to the method to be described in this paper. It was thought that, if a constant abnormal stimulation could be applied to the epiphyseal plate, an increase in the activity of the cartilage cells would take place, and growth would increase. Venable and Stuck have shown that, if two metals of different potentials are inserted into the body tissues, an electric current is generated between them, causing heat and electrolysis. It was assumed that, if two different kinds of metal were inserted into or around the epiphyseal plate, they would act as

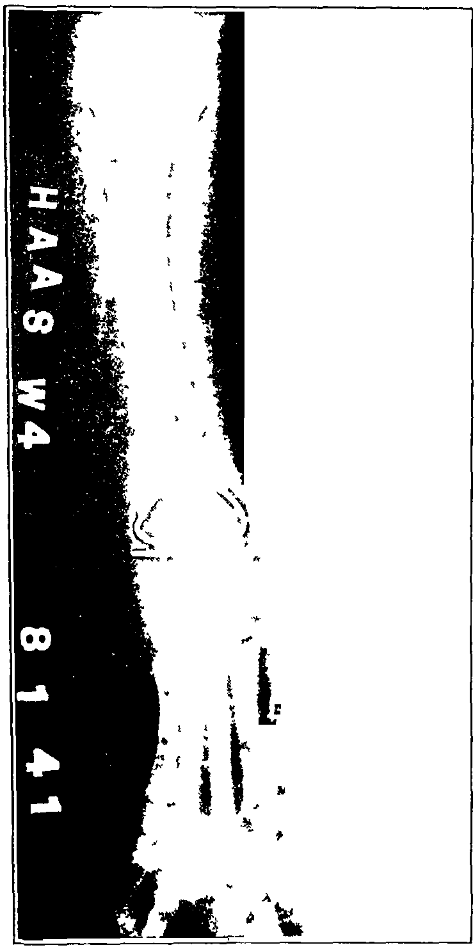


Fig. 2-A

Dog 4-W. Showing wire as originally placed.

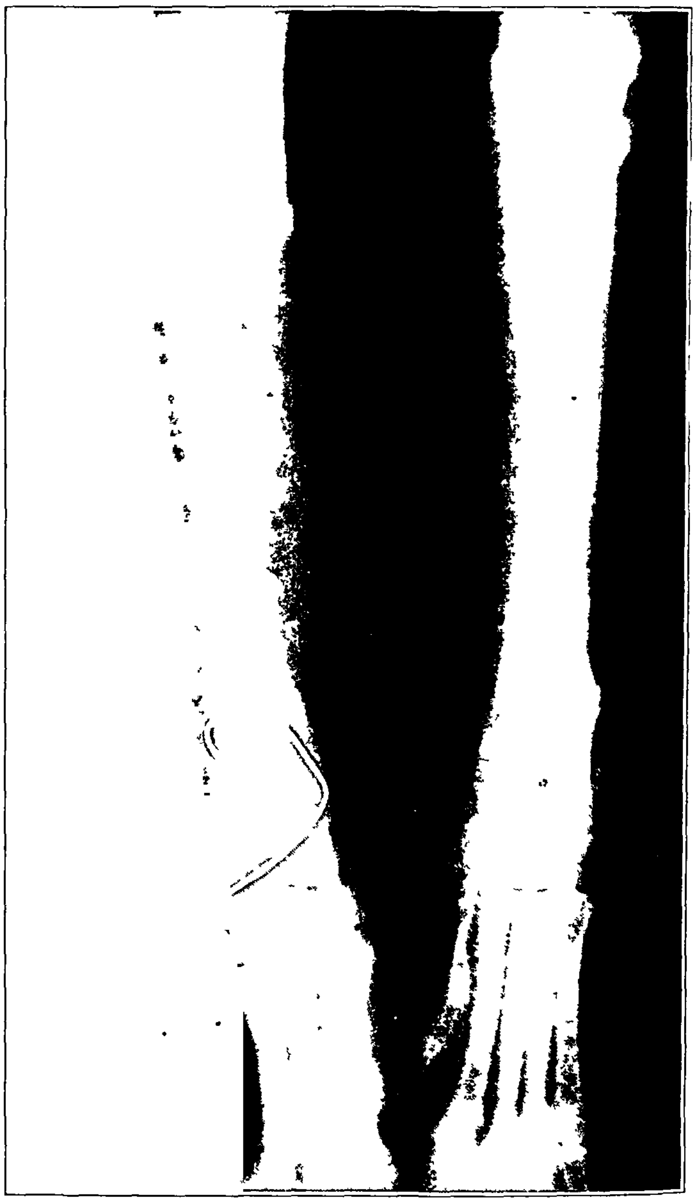


Fig. 2-B

Showing the opened wire loop. The restraining force of the wire has caused 2.5 centimeters loss of growth.

a constant stimulator to the cells, and that growth increase would take place. Suffice it to say that, in a series of experiments, where various combinations of metals were placed around the epiphyseal plate, no additional growth in length took place in the bones.

In one of the series of stimulation experiments, a free wire loop was placed around the epiphyseal plate in the frontal plane. As growth took place and the epiphysis grew distally, the wire loop opened up. In comparing the two extremities at the conclusion of the experiment, it was noticed that there was a loss of growth in the limb with the wire loop. This loss was interpreted as being due to the restraining tension of the loop, which

FIG. 3-A

Dog 9-1. The wire has been passed through the plate diagonally. There is a greater loss of growth on the lateral side of the plate than on the other.

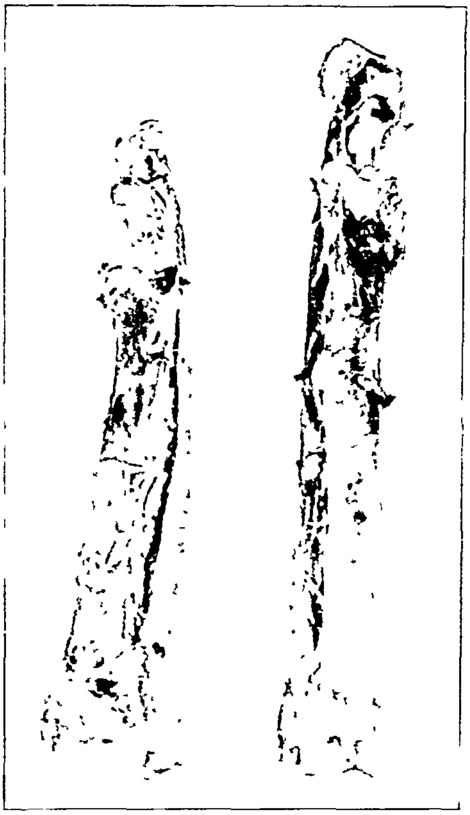


FIG. 3-B

Gross specimen, showing the discrepancy in length.

had hindered normal length growth. Following this observation (that longitudinal growth of bone could be mechanically hindered), a series of experiments was performed, in which a wire loop, passed around the epiphyseal plate, bound the epiphysis to the diaphysis. This was done to confirm the previous findings and to determine whether or not the method had practical value.

Before describing these experiments, a brief review of the mechanism of length growth is in order. We know that there is no interstitial growth in normal growing bone. A small amount of growth is due to the expansion of the articular end of the epiphysis, as shown by Siegling in his observations on phosphorus feeding. Length growth is dependent upon an intact epiphyseal cartilaginous plate. The longitudinal columns of cartilage are responsible for length growth, and are the important portion of the epiphyseal plate. These columns of cartilage are a part of the epiphysis. The provisional buds of cartilage and osteoid tissue expand by cell growth and multiplication, pushing the epiphyseal cap away from the metaphysis, and thus increase the length of the bone. The force exerted by this growth in the lower extremities in the erect position must be strong, to raise the weight of the body, as well as to overcome muscle tension. The force in recumbency would not have to be so great, and it would be expected that length growth would be greatest during the time the body was flat, providing circulatory and metabolic processes were uniform.

A few representative experiments will be described, in which operations to retard the longitudinal growth of bone were performed upon dogs. Results will also be reported in two growing children in whom the same method of inhibition was utilized.

Measurements of length in the following experiments have been taken directly from

the roentgenograms. The amount of growth from either epiphyseal plate was determined by measurement from a fixed point on the wire on the diaphyseal side. Errors are minimal, since care was taken to employ the same distance from the target to the bone, and from the bone to the plate, in the roentgenograms of each dog.

Experiment 3-W.B

Method. After exposure of the distal portion of the radius of a growing dog, a wire was passed transversely through the epiphysis. It was then turned proximally along the periosteum, across the epiphyseal cartilaginous plate, and back through the diaphysis transversely. The two ends were then hooked together under tension. Thus the epiphysis and diaphysis were bound together by the wire loop which passed completely around the plate. An additional piece of wire was placed through the epiphysis within the loop (Figs. 1-A and 5).

Result. Fifty-five days later, the wire loop was found unfastened and opened (Fig. 1-B). The length growth of the normal side was 3.5 centimeters, and that of the side operated upon 2.5 centimeters; 1.3 centimeters of growth had taken place from the upper end of the bone, and 1.2 centimeters from the lower end. Growth was not entirely stopped, but was impeded about 1 centimeter. The wire loop impeded all growth, until it became unfastened, and then impeded growth only to the extent of the force necessary to open the wire.

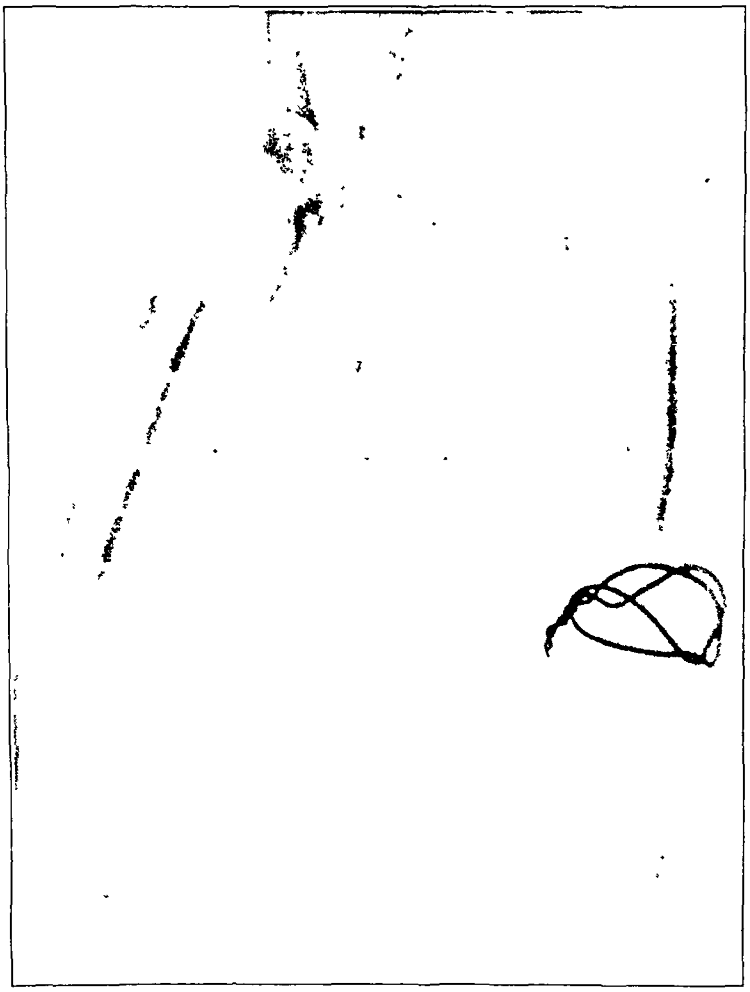


FIG. 4

Dog 9-B. A double loop of wire has been placed about the lower epiphyseal cartilaginous plate of the femur, causing 2.0 centimeters loss of growth.

Experiment 4-W

Method. A wire was inserted through the distal radial epiphysis of a growing dog, as in the preceding experiment, over the epiphyseal plate, and back through the diaphysis. The ends were overlapped and left free (Figs. 2-A and 5).

Result. At the end of 117 days, there had been 2.2 centimeters loss of growth in the limb which had been operated upon. Figure 2-B shows how the wire loop was distorted by the growth of the bone. There was a total growth of 5.5 centimeters in the normal limb, and 3.3 centimeters in the limb which had been operated upon; 1.9 centimeters of this growth was from the upper plate, and 1.4 from the lower plate. A considerable force must have been necessary to open the loop of wire. (The normal ratio of growth of the radius is 20 per cent from the upper plate and 80 per cent from the lower plate.)

Experiment 9-1

Method. A German silver wire, just under 0.12 of a centimeter (three sixty-fourths of an inch) in diameter, was passed transversely through the distal epiphysis of the radius of a growing dog; then it was passed diagonally through the epiphyseal cartilaginous plate to emerge on the diaphyseal side opposite. It was then passed transversely through the diaphysis and diagonally back through the plate to emerge on the side of the epiphysis approximately where it started. The ends were fastened together by twisting. Thus the diaphysis was bound to the epiphysis through the plate by a wire figure-of-eight (Fig. 5).

Result. Two hundred and eighty-three days later, there was 4 centimeters of growth on the normal side. The radius which was operated upon showed 2.2 centimeters loss of growth on the lateral side and 1.7 centimeters loss on the medial (ulnar) side. The discrepancy between the two sides was due to the fact that the wire broke on the lateral side, and did not pass vertically across the epiphysis. This allowed more growth on the lateral side, thus making an oblique joint articulation (Figs. 3-A and 3-B).

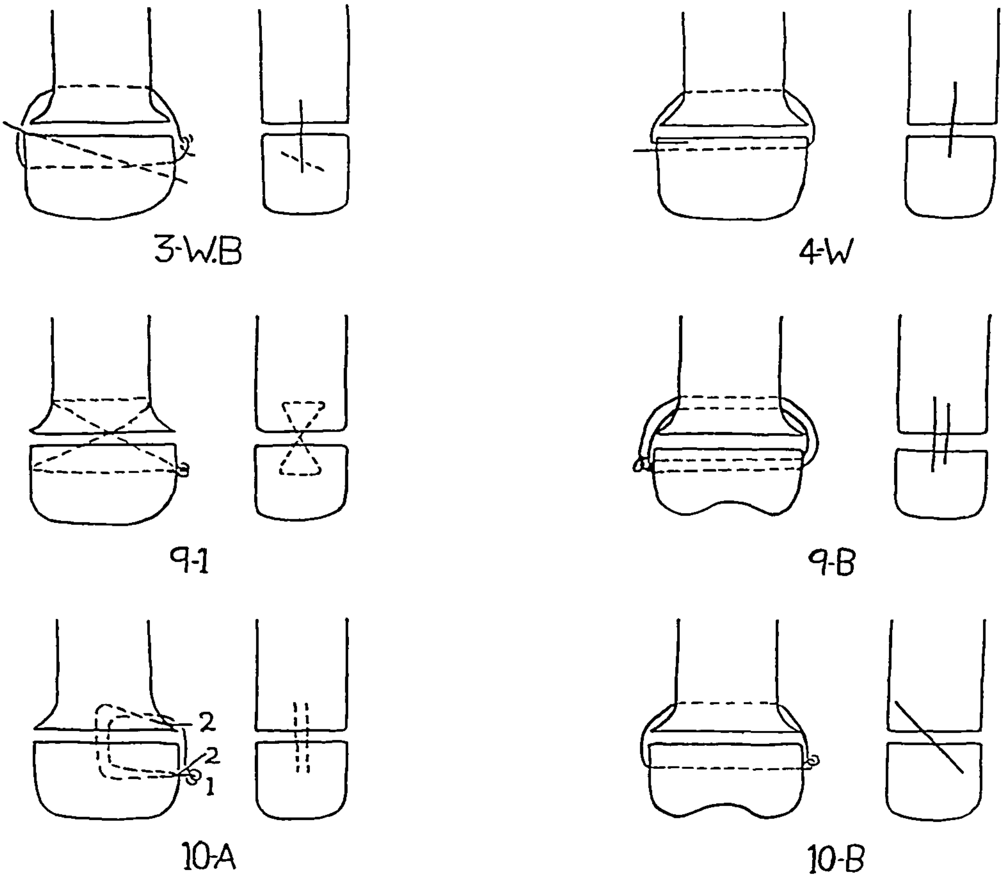
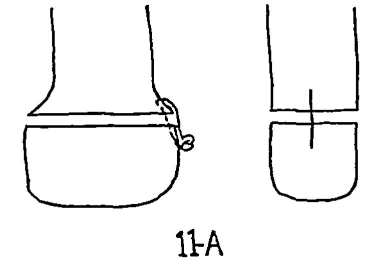


FIG. 5

Diagrammatic representation of the procedures followed in e experiments.



cperiment 9-B

Method. The method was the same as that used in 3-W.B, cept that both ends of the wire were passed around the plate; e distal end of the femur of a growing dog was employed for e experiment, and the extra wire marker was omitted.

Result. Two hundred and sixty-seven days later, the tal normal growth was 3.6 centimeters. There was 2.0 centi-eters loss of growth in the bone with the wire loop. The distal piphyseal plate had not contributed much to the increase in length, as 0.9 centimeters of the 1.6 centimeters growth in the limb with the wire was from the proximal epiphyseal plate. There was some absorption bout the wire, which may have allowed some growth from the lower plate.

xperiment 10-A

Method. A wire was passed into the distal epiphysis of the radius of a growing dog, through the epiphys-al plate into the diaphysis, to emerge on the medial side of the radius; the ends were twisted together under ension. A second wire was placed approximately parallel to the first; the ends of it were left free (Fig. 5).

Result. Three hundred and two days later, the normal growth was 3.9 centimeters. There was a loss f 2.3 centimeters of growth of the wired bone. Of the total growth of 1.6 centimeters, only 0.6 of a centi-neter took place from the lower end, in contrast to 1.0 centimeter from the proximal epiphyseal plate. The rticular end of the radius had become oblique, due to the greater restraining force on the ulnar side. The wisted wire was broken and the ends were separated during the limited growth.

Experiment 10-B

Method. A copper wire, 0.04 of a centimeter (one sixty-fourth of an inch) in diameter (No. 26), was passed ransversely through the posterior part of the distal femoral epiphysis of a growing dog, obliquely across the piphyseal plate, then transversely through the diaphysis near the dorsal surface. The ends of the wire were astened by twisting under tension (Fig. 5).

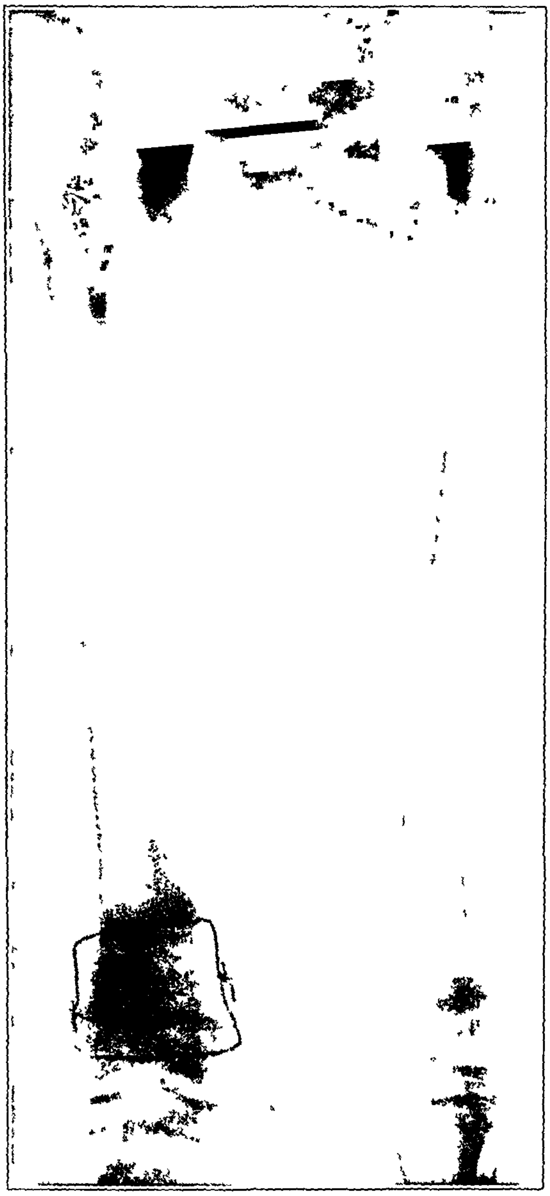


Fig. 6-A
Case 1 E G July 30, 1942, antero-posterior view, showing the wire as placed at the time of operation (March 27, 1942)

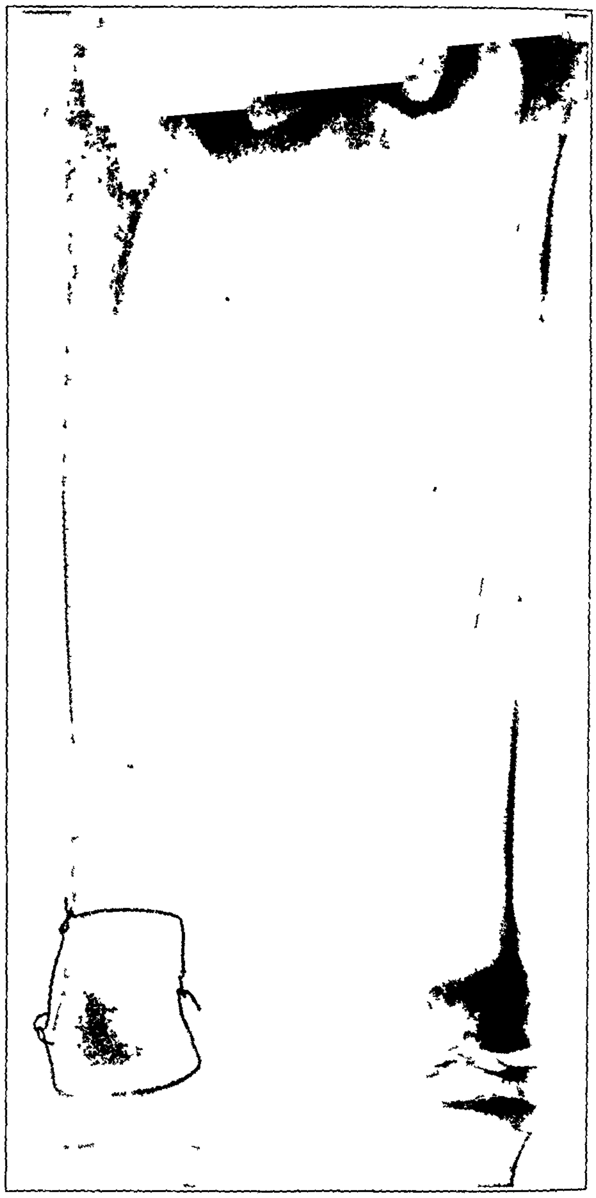


Fig. 6-C
July 12, 1944. Showing wire after it had broken and been refastened

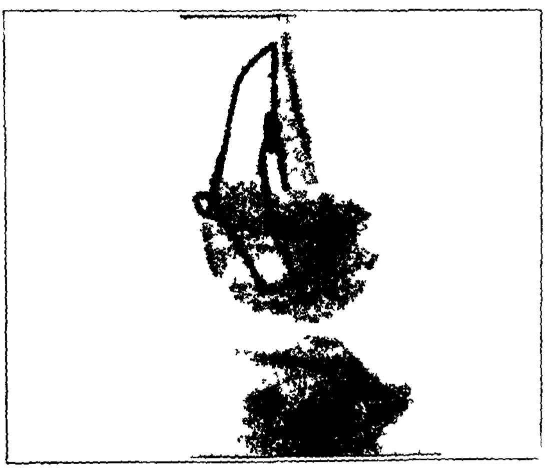


Fig. 6-B
July 30, 1942. Lateral view.

Result. Two hundred and eighty-seven days later there was only 0.7 of a centimeter loss of growth. On examining the gross specimen, the wire was found to be on the dorsal surface of the bone. Since it had been passed through the diaphysis near the dorsal surface, it had pulled out, as growth took place, and thus had exerted very little restraining force.

Experiment 11-A

Method A wire was passed through the periosteum of the epiphysis and directed vertically, so as to lie beneath the periosteum of this portion of the bone, the perichondrium of the plate and the periosteum of the diaphysis through which it emerged a little above the plate The ends were fastened together under tension (Fig. 5).

Result. Three hundred and one days later, there was no loss of growth. This shows that the operative approach to the plate did not disturb growth, and that there was little restraining force when the wire did not bind the epiphysis to the diaphysis.

TABLE II

Growth of Femur in S. B.

Date	Normal Femur (*Centimeters*)	Short Femur (*Centimeters*)	Difference (*Centimeters*)
March 30, 1942	37.8	34.6	3.2
April 1, 1942 (operation)	....	....	..
April 15, 1943	39.1	35.9	3.2
September 30, 1943 (wire found broken)	40.3	36.8	3.5
October 8, 1943 (wire refastened)	....	....	..
May 11, 1944	40.6	37.8	2.8
Total growth	2.8*	3.2	

* Growth from wire to femoral head was almost 1.6 centimeters; growth from wire to lower articular surface was 1.2 centimeters.

electrolytic reaction. There was no evidence of any defect in the wire, and it is hardly likely that there could be sufficient stress produced by the expanding force of a growing plate to cause the wire to break. It is possible that there was an electrolytic reaction which weakened the wire by corrosion and oxidation. It is known that electrolytic reaction is set up in metal at a bend. This is a possibility in the case under discussion.

Case 2. S. B., male, aged ten years, had had poliomyelitis at the age of four and a half years. The left lower extremity was about 6.7 centimeters (two and five-eighths inches) shorter than the right.

On April 1, 1942, a wire loop was passed around the epiphyseal cartilaginous plate in the frontal plane. On September 30, 1943, a roentgenogram showed that the loop of wire had broken. On October 8, 1943, the ends were again connected with a piece of wire (Table II).

The measurements show that the two femora have grown about the same amount. In checking the results, it is noticed that the growth from the wire to the head of the femur is almost 1.6 centimeters; therefore, it would be anticipated that the growth would have been at least 3.6 centimeters from the lower epiphyseal plate. There has been only 1.3 centimeters contributed by the lower epiphyseal plate. Therefore, in spite of the fact that the wire had broken, there has been a considerable inhibition of growth. The total measurement of the two extremities is now almost equal in length, because of an additional lengthening operation on the tibia and fibula on the affected side. With an anticipated continued increase in length of the normal extremity, it seems advisable not to remove the wire, so that the growth discrepancies will not be too great at the termination of the growing period. The fact that growth took place after the wire broke, again shows that the restraining loop only temporarily inhibits growth, and does not destroy the normal power of proliferation of the plate.

SUMMARY OF RESULTS IN PATIENTS

In only two of the five patients upon whom wiring operations have been performed, has a sufficient time elapsed to draw any conclusions.

Because growth is relatively slow in man, determination of the practicability of the method of wiring the epiphyseal plate described herein must await the results obtained after a long period of time.

From the results obtained thus far on patients, there is definite evidence of growth retardation, and a continuation of the method seems warranted. The epiphyseal plate maintained its length-growing function, after being held in check by the wire for a considerable period of time. This is shown by the fact that following the breaking of the wire, which had been in place for a year, growth increased.

DISCUSSION

The methods of anticipating length of growth are, at best, speculative, because there are a number of factors that may change the rate and amount of growth. Although there are guiding tables of averages, the rate of abnormal growth cannot be calculated.

If growth can be controlled by alternately releasing and tying the wire loops, growth etardation may be instituted at a much earlier period, because, unlike resection of the piphyseal plate which is permanent, the retardation is present only while the wire loop s in place. A metal band may give a wider surface of contact, and a removal band could e attached to the ends for controlling the fixation.

The wire around the plate did not produce any deformity, except when unilateral orce was applied. Taking advantage of unilateral restriction, one may correct deformity ollowing partial injury with arrest of growth on one side of the plate, by wiring the opposite side. It is also possible that such a corrective procedure could be applied in case of genu valgum or genu varum, by putting the wire around one side of the plate.

CONCLUSIONS

A wire encircling the epiphyseal cartilaginous plate in the frontal plane will stop ength growth from that plate.

Growth may be controlled by a wire loop, by alternately stopping and allowing normal growth as the loop is tied or untied.

Length-growth equalization may be started at an earlier age.

Unilateral growth may be counteracted by a wire loop around the plate on the side of overgrowth.

The operation should not be performed until sufficient ossification of the epiphysis has taken place,—that is, after about eight years of age.

DISCUSSION

Dr. John Royal Moore, Philadelphia, Pennsylvania: I wish to congratulate Dr. Haas on his original contribution. Growth arrest through epiphysiodesis has become a well-known and useful procedure in the equalization of extremity length. The principal difficulty is estimating the prospective length of the two extremities, or comparable bone involved. Dr. Haas has proposed a method by which we can arrest temporarily the growth of the more rapidly growing bone, then release it and have a resumption of growth. The illustrative cases are few, but very convincing. Temporary arrest until equalization has taken place would seem to be of very practical value.

Dr. J. Warren White, Greenville, South Carolina: I also want to congratulate Dr. Haas on this unique idea. There is a question in my mind, however, as to whether this delicate, highly differentiated tissue can stand the tremendous pressure which must be put on it to bring about the arrest of growth, and then start growing again after the pressure is released. That will be brought out in due course of time.

In the ten years prior to January 1, 1943, at the Shriners' Hospital in Greenville, 202 epiphysiodeses on 148 patients have been done. I became mildly interested in the procedure as a supplement to the shortening operation I had been doing for the previous five years. It has been a most interesting project.

One reason for my interest was the fact that, in fast-growing children. 25 to 50 per cent. of our gain in equalization was lost during the subsequent year or two after the shortening procedure. This I felt to be due to the growth stimulation of all the epiphyses of the very leg we wished to shorten.

In this group of "arrest cases", as I like to call them for short, eighteen femoral shortenings were done largely as supplementary measures. These, except for three performed in 1942, were all done in the first five years, thus showing that this procedure has been largely outmoded, except for adults or those children seen late in their growth period.

By and large, we have been well satisfied with our results. In our entire series, there have been few unfortunate developments, and most of these have resulted from overenthusiasm in doing multiple arrests early in the game. These required nine compensatory operations on the "short" side.

While we regret that these overcorrections have occurred, it shows that we have been attacking the problem aggressively, and you may be sure these particular cases have been carefully reviewed and will be reported.

This series of cases has added tremendously to the interest in the work of our end-result clinics, and in only ten or a dozen cases have we been unsuccessful in our follow-up.

Although we admit its immediate inaccuracy, we have employed exclusively what we call leg-length roentgenograms to record our discrepancies. The technique of this has been published, and has been found to be of much practical value. For several months a number of years ago, we took two exposures, and found that rarely did an error of more than 0.3 of a centimeter occur. It is so satisfactory, when reviewing a series of cases, to have tangible data to refer to, rather than records of tapeline measurements. We have averaged

well over six leg-length roentgenograms per patient, making well over 1,000 films in this series of 150 cases. This adds somewhat to the expense of the care of these patients, but we have felt that it is well worth it, and that, in this problem, accuracy in the recording of length discrepancies is of paramount importance. The error that exists in this method carries through the entire series, and tends to cancel itself.

The annual decrement in the discrepancies resulting from arresting growth at the distal end of the femur, preliminary report of which has been published,* is still holding good, and, regardless of the size or age of the individual during the growth period, we figure on 0.9 of a centimeter; at the proximal tibia and fibula we figure on 0.6 of a centimeter. Only two arrests have been performed at the distal tibia and fibula; but from these the annual decrement is considered to be 0.6 of a centimeter.

This means that the annual decrement is really less than the 0.9 and 0.6 of a centimeter mentioned, but as all figuring is based on the leg-length roentgenograms, this error also is cancelled.

In our calculations we have figured that girls grow until seventeen years of age and boys until eighteen, a point which explains our rather large number of overcorrections. Hereafter, we shall calculate that growth stops one year earlier.

In our series, the causes of the discrepancies were as follows: poliomyelitis, eighty-five, or 57 per cent.; congenital deformities including club-foot and arthrogryposis, 17 per cent.; osteomyelitis, 12 per cent.; and ankylosed hips from septic arthritis or tuberculosis, 12 per cent. As compensatory tilting of the pelvis in this latter group is impossible, much more accuracy is necessary in equalizing limb length, and over half of our compensatory arrests were done for the final refinement in those cases.

In no instance in these ten years have we had to correct varus or valgus deformities following the use of this technique, and in only two instances have deformities been noted. In one patient with arthrogryposis, who is now only thirteen years of age, deformity recently occurred; this will probably have to be corrected. We are not sure that our operation has caused the deformity. In another, deformity has resulted from a definite error in technique, but it did not show up until the boy had reached his full growth, and was not severe enough to require an osteotomy.

A great many orthopaedic surgeons have been hesitant about embarking on this problem, as most of the papers discussing it have, in my opinion, stressed too much the need of extreme accuracy in calculations. There are so many other variable factors in bone growth, over which we have no control, that I feel we are likely "to miss seeing the woods for the trees".

I would like to suggest that our Committee on Scientific Research establish a subcommittee on this discrepancy problem, as much needs to be done in working out a practical plan that can be followed easily by those whose chief interest is not in this particular problem.

Dr. Dallas B. Phemister, Chicago, Illinois: My experience with the growth-arrest operation for leg equalization has been similar to that of Dr. Wilson,—namely, that the surgeon usually errs on the side of conservatism, and, when the ultimate result is obtained, the limb in which growth was arrested is either of approximately the same length as the opposite one, or it is somewhat longer. Consequently, I believe that the fear of producing too much growth arrest, which is the greatest factor in causing surgeons to desist from doing the operation, is not justified by experience. Dr. White's report is the only one I know of in which several patients obtained too much growth arrest. I have had only one case in which there was failure of growth arrest on one side of the epiphysis, resulting in angulation of the limb. The condition was recognized early, and this side was fused by a second operation. If one follows the patient carefully, the failure of growth arrest on one side may be detected early, and a second operation may be performed. Consequently, the occasional occurrence of this complication should be no bar to the use of the operation.

Dr. Haas's work is evidence that he still possesses the power of original observation which has always characterized his publications. I would not be surprised, if much practical use is made of this procedure, both for length equalization and for the correction of the deformity produced by incomplete growth arrest.

Angulation of an extremity, from destruction of part of an epiphyseal cartilaginous plate by osteomyelitis or traumatic separation of the epiphysis, is a not uncommon condition which may be avoided, if the patient is carefully observed and an early growth-arrest operation is performed on the remaining open portion of the cartilaginous plate. It is an important use of the operation, and many serious deformities may thus be avoided.

Lieutenant Gerald G. Gill, Chickasha, Oklahoma: Dr. Haas is to be congratulated upon his finding of a method of temporarily retarding epiphyseal growth. This method may have a wide range of usefulness. However, two questions immediately present themselves and will undoubtedly be answered by Dr. Haas in due time. First, is the rate of growth normal after the removal of the wire which has retarded growth? Second, does the epiphyseal center thus retarded continue to grow as long as the normal center or does premature closure occur?

Dr. Wilson's paper very completely presents the difficulties which have beset those using epiphyseal

* White, J. W., and Warner, W. P., Jr.: Experience with Metaphyseal Growth Arrests. Southern Med. J., XXXI, 411, 1938.

arrest for the equalization of the length of the limbs in children. The errors in equalization found by Dr. Wilson, usually on the side of insufficient growth retardation, have been the experience of many surgeons. On the other hand, in a few instances, as pointed out by Dr. White, too much growth retardation has resulted.

In my opinion, these errors in prediction are, for the most part, caused by differences in sexual and skeletal maturation in children of a given age. In other words, children of the same chronological age often differ widely in their skeletal or sexual maturity. These variations may be determined by the assessment of the bone age by the method of Todd. It is my belief that these errors in equalization may be decreased, if, in each case, bone-age determinations are made.

Our knowledge of the growth of children is still very incomplete, and we should take every opportunity to gather exact data to complete our knowledge. For this reason, I believe that, in each case, metallic markers should be implanted in each bone, and that measurements should be made by roentgenographic methods, preferably scanography, so that the growth from each epiphyseal center may be measured. It follows that an accumulation of such data will increase our knowledge of the growth process, and will enable us to perfect our methods of prediction of growth. Only in this way will the use of epiphyseal arrest be placed upon a firmer footing.

Dr. S. L. Haas, San Francisco, California: It is believed that the growth in length is suppressed, but not permanently destroyed by the wire loop around the epiphyseal plate. If the roentgenograms, showing the wire loop intact for one and a half years, are compared with the two subsequent plates taken at intervals after the wire loop had broken, the widening of the loop and separation of the broken ends are seen. This is considered as sufficient evidence that the growth property of the plate was only temporarily inhibited while the wire was intact.

It is recommended that retardation by the wire loop be not attempted on a child under the age of eight years, because before this age the epiphyses consist of too much cartilage, and this may allow the wire to cut through and so permit growth to proceed.

All growth measurements are made on roentgenograms taken at a five-foot target distance.

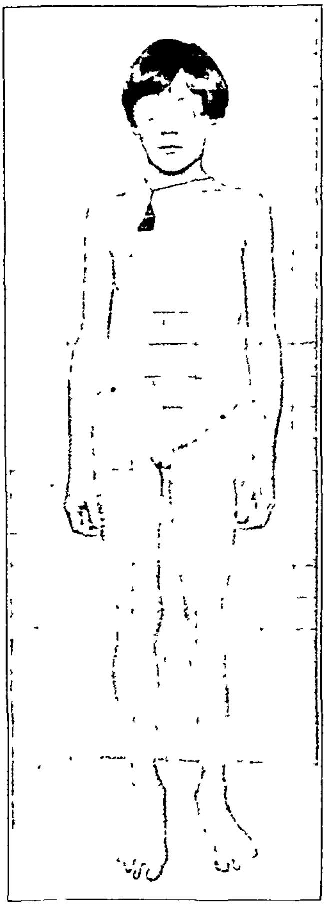


Fig. A

D. F., aged twelve years in 1930, had had poliomyelitis several years earlier. Her left lower extremity was 4.25 centimeters (1¾ inches) shorter than the right. A left lumbar sympathectomy was performed November 24, 1930.

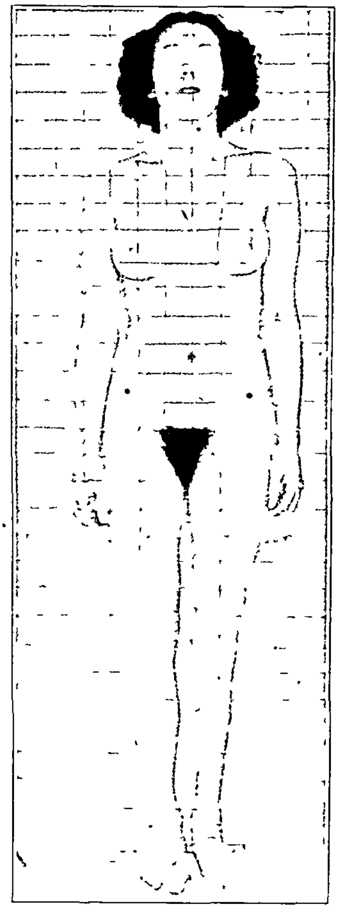


Fig. B

In 1937, when she was nineteen years of age, the left limb was 0.6 of a centimeter (¼ of an inch) shorter than the right. Most of the rapid growth, which resulted in the decrease in the discrepancy, occurred in the first three years after operation.

Lieutenant Colonel T. C. Thompson, Washington, D. C.: I have nothing to add, except that it seems our results are not so good as Dr. White's or Dr. Phemister's. We have no apology to make for our failures, except that the operations were done by a number of surgeons in a big teaching institution. Many were done by house officers under the direction of the attending men, so that the operative procedure may not have been as technically accurate as it should have been.

Dr. Haas is to be congratulated in getting arrest of growth without deformity in small animals.

Colonel R. I. Harris, Toronto, Ontario, Canada: Dr. Haas has made the statement that among the methods which have been advanced

to produce equalization of limb length, lumbar sympathectomy is impractical, since the increase in limb length is uncertain and insignificant in amount. This is scarcely a fair assessment of the value of the procedure. It is our experience, based upon several hundred operations, that, when by lumbar sympathectomy the full vasodilator effect is secured and is maintained, enhancement in the rate of growth of the extremity always occurs. It is true that a wide variety of factors may act to impair the perfection of the result, but, under favorable circumstances, cessation of the progressive shortening can be counted upon, and, not infrequently, the shortness is overcome. The greatest gain which I have accomplished is 3.75 centimeters, as is shown in the accompanying illustrations (Figs. A and B). [See article by R. I. Harris and J. L. McDonald: The Effect of Lumbar Sympathectomy upon the Growth of Legs Paralyzed by Anterior Poliomyelitis. J. Bone and Joint Surg., XVIII, 35, Jan. 1936.]

J. L. McDonald, M.B., Toronto, Ontario, Canada: I am disappointed that Dr. Haas should dismiss the value of lumbar sympathectomy in patients with a short lower extremity—particularly with a short limb resulting from infantile paralysis—without further discussion.

Since the first lumbar sympathetic ramisection was performed by Colonel R. I. Harris at the Hospital for Sick Children, Toronto, in 1928, it has been repeated in over 400 cases, over 80 per cent. of these being in patients with a short limb resulting from infantile paralysis. In the first few cases, a lumbar sympathetic ramisection was performed, but during the past fourteen years all patients have had the sympathetic trunk and ganglia completely removed from the level of the second lumbar downward. We have found in these cases that the effect following sympathectomy has been sufficiently encouraging to continue the operation as a routine procedure in all patients showing a beginning difference in the length of the extremities following infantile paralysis. It is our practice to measure the length of the limbs in patients recovering from infantile paralysis, who have leg involvement, at frequent intervals; and, as soon as there is any evidence of difference in length, we carry out a lumbar sympathectomy on the affected side.

It is interesting to note that, following the 1937 epidemic of anterior poliomyelitis, the largest ever recorded in the Province of Ontario, we have had a relatively small number of patients showing shortening of the lower extremity. This again demonstrates that there are many factors involved in the etiology of the short limb besides disturbance of circulation.

Note: The paper on "Equalization of Leg Length with Comparison of the Results of Epiphysiodesis and Femoral Shortening" by Dr. Philip D. Wilson and Lieutenant Colonel T. Campbell Thompson, presented at the same session, has not yet been published.

CONCENTRIC ARTHRODESIS OF THE ANKLE JOINT

A Transmalleolar Approach *

BY ROGER ANDERSON, M.D., F.A.C.S., SEATTLE, WASHINGTON

Operations for fusion of the ankle joint are indicated for serious infections, flail joints, and especially traumatic arthritis. The joint sequelae of ankle fractures are frequently caused by incomplete reduction, but persistent ankle symptoms occasionally follow a perfectly reduced fracture. War injuries will further increase the number of cases of traumatic arthritis. Loss of cartilage or bone from compound fractures is prevalent among paratroopers and men in other branches of the Service, where the traumatic force is apt to be direct and explosive.

Since the disabling symptoms of traumatic arthritis can be eradicated by successful fusion, the importance of arthrodesis is apparent. The author believes that present-day procedures for arthrodesis leave much to be desired technically, and in the results obtained. First, there is the difficulty in visualizing and gaining working access to all compartments of the joint. Then, an even resection of the cartilage and subchondral bone from the entire joint, including the posterior portions, through the commonly advocated anterior approach, has its perplexing anatomical restrictions. It is exasperating to attempt through this approach, to resect the exact amount of bone for the desired degree of equinus, especially in procedures that call for a buttressing bone graft. To resect the convex talus and the concave tibia with an osteotome sufficiently to get full apposition calls for resection of unequal thicknesses of the subchondral plate. Then, if postoperative roentgenograms reveal improper angulation or poor contact, the bone graft hinders correction. Furthermore, the accepted anterior approach does not lend itself to the safe treatment of discharging suppurative lesions of the ankle joint.

Another cause of poor results, and an important one, is unsatisfactory immobilization. A circular cast, even though it extends to the upper thigh, will not absolutely immobilize the ankle in an ambulatory patient. As the swelling recedes and atrophy occurs, the cast becomes loose; and, as the crutch-ambulatory patient raises his foot off the floor, gravity continues to pull downward on the cast. Since a loose cast rests chiefly on the dorsum of the foot, a separation at the ankle joint occurs. Then, as the patient rests his foot on the floor, the ankle joint is forced together. Such alternate contact and separation is not conducive to bony ankylosis.

TRANSMALLEOLAR APPROACH

By the transmalleolar approach, the ankle joint can be easily resected, and the pitfalls of accepted methods may be avoided. The basis of this method is a bilateral approach to the ankle joint by subperiosteal resection of the malleoli. Once the malleoli have been removed, the entire tibiotalar articulation is accessible to the surgeon. Incomplete contact resulting from impingement of the malleolar tips is eliminated by resection of these structures.

CONCENTRIC ARTHRODESIS

The second step in the procedure is equally important and has been made possible by the bimalleolar approach. It consists in resection of cartilage and subchondral dense bone in such a manner that the resulting cancellous bone surfaces are concentric. Such resection can be conveniently effected by means of a special curved osteotome (Fig. 2).

*Demonstrated at the Scientific Exhibit, The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 22 to 26, 1944.

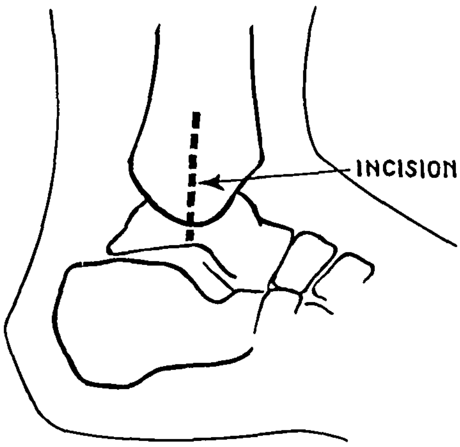


FIG. 1-A

Through a medial skin incision, the medial malleolus is subperiosteally resected. The malleolus may be discarded or may be cut up into small pieces and later used as grafts.

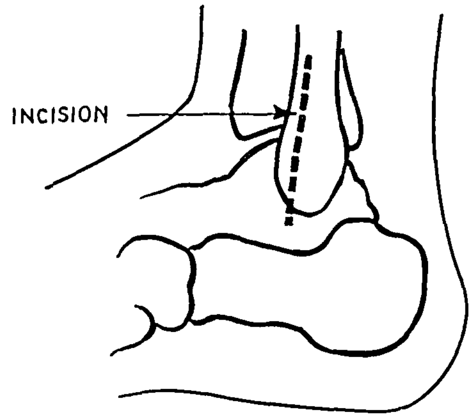


FIG. 1-B

Through a lateral incision, the lateral malleolus is also subperiosteally resected. If indicated, this malleolus may be likewise utilized.

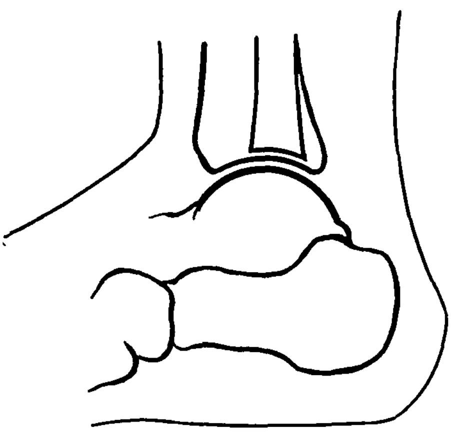


FIG. 1-C

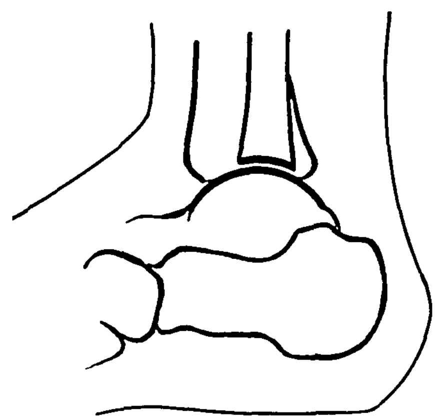


FIG. 1-D

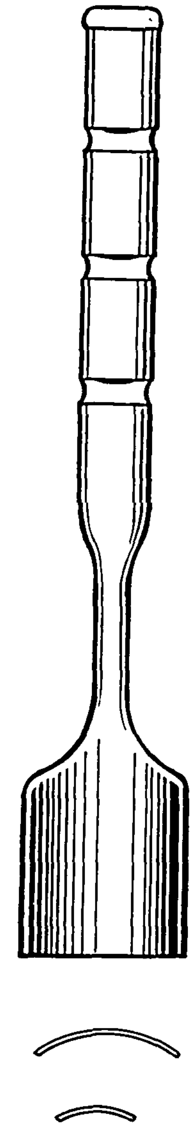


FIG. 2

Fig. 1-C: The resected ankle exposed.

Fig. 1-D: Since the curve of the contacting surfaces corresponds to that of the ankle joint, contact is complete, regardless of the degree of equinus.

Fig. 2: Thin osteotome, the curve of which corresponds to the arc of the ankle joint. The two widths are illustrated in the foreview. The curve of the osteotome corresponds to the arc of a circle which has a diameter of 3.8 centimeters (1½ inches).

The concentrically resected joint permits maximum contact between the tibia and talus, regardless of the degree of equinus. If the postoperative position is not satisfactory, the foot can be placed in the exact amount of equinus desired, without loss of bony contact.

J. R. Moore has suggested to the author that additional stability can be gained by fusing the distal fibula tc the tibia.

SUPPURATIVE ARTHRITIS

This method lends itself admirably to the treatment of suppurative arthritis. The approaches by resection of the malleoli provide excellent drainage channels. The technique has been successfully used for acute infections and for chronic cases where there has been extensive destruction of cartilage and adjacent bone, with abscess formation and profuse discharge.

In badly infected cases, in which discharge persists following the operation, the con centric resection may not result in bony union. However, this procedure provides a saf means of obtaining early closure of the compound wound, and usually the fibrous unioı

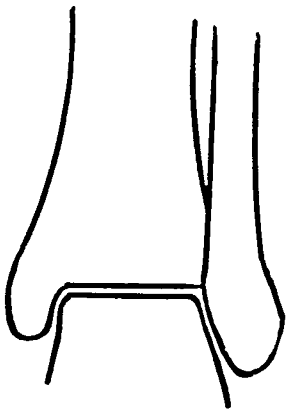


FIG. 3-A

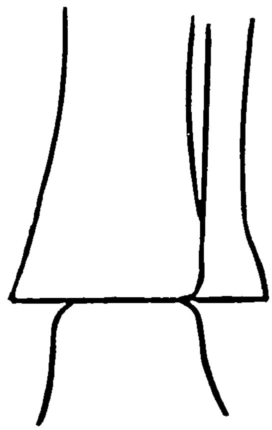


FIG. 3-B

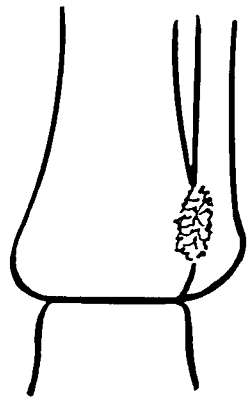


FIG. 3-C

Fig. 3-A: Illustrates the relationship at the ankle joint before resection.
Fig. 3-B: Subperiosteal resection of the malleoli produces an apparent broadening of the ankle.
Fig. 3-C: The bases of the malleoli are reshaped, as illustrated. Excess bone may be placed around the ankle joint in the form of small grafts. Prominence of the anterior and posterior margins of the tibia may be similarly treated. Through the lateral incision, synostosis is produced on the anterior side between the fibula and tibia.

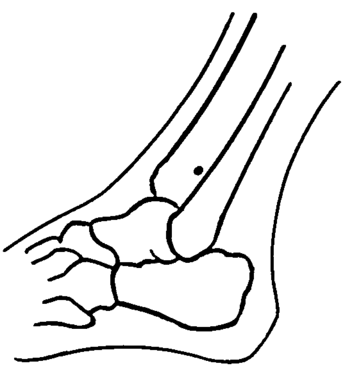


FIG. 4

Illustrates the site for the single transfixion pin used in the routine technique. The pin should be placed just superior to the incision.

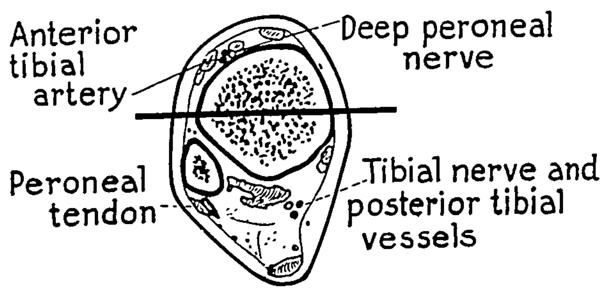


FIG. 5

Depicts the anatomical feasibility of placing the transfixion pin through the tibia.

FIG. 6

The castless method of immobilization is accomplished through the placement of two transfixion pins (or Kirschner wires) in the tibia, one through the os calcis, and one through the talus, in conjunction with medial and lateral fixation rods. While there are several advantages to the castless method, unfortunately the tarsal bones are so cancellous and relatively narrow that they do not tolerate transfixion pins as well as the long bones.

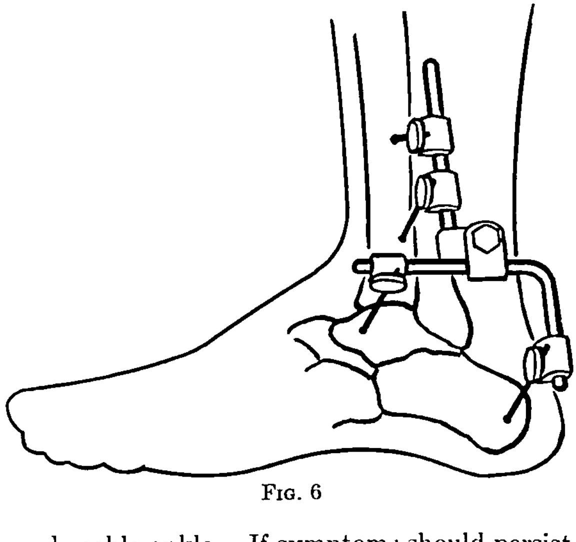


FIG. 6

that results is sufficient to give a pain-free and usable ankle. If symptoms should persist, a second concentric arthrodesis may be resorted to.

When it is obvious from the outset that amputation or an arthrodesis is inevitable, because of actual loss of bone or extensive trauma to the cartilage of the weight-bearing

FIG. 7-A

Illustrating the location of the transfixion pins for castless immobilization.

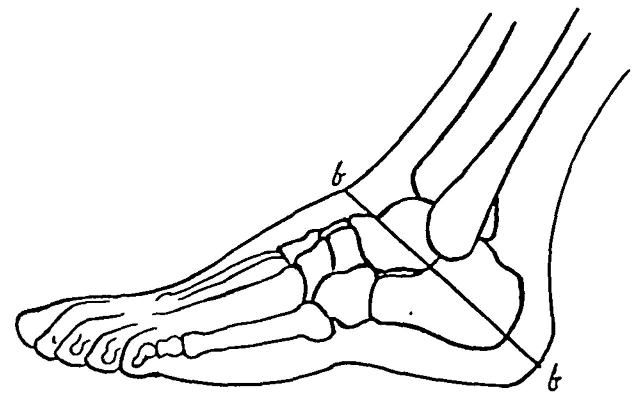


FIG. 7-B

The line *b-b* denotes the level at which the cross sections, shown in Figs. 7-C and 7-D, were made.

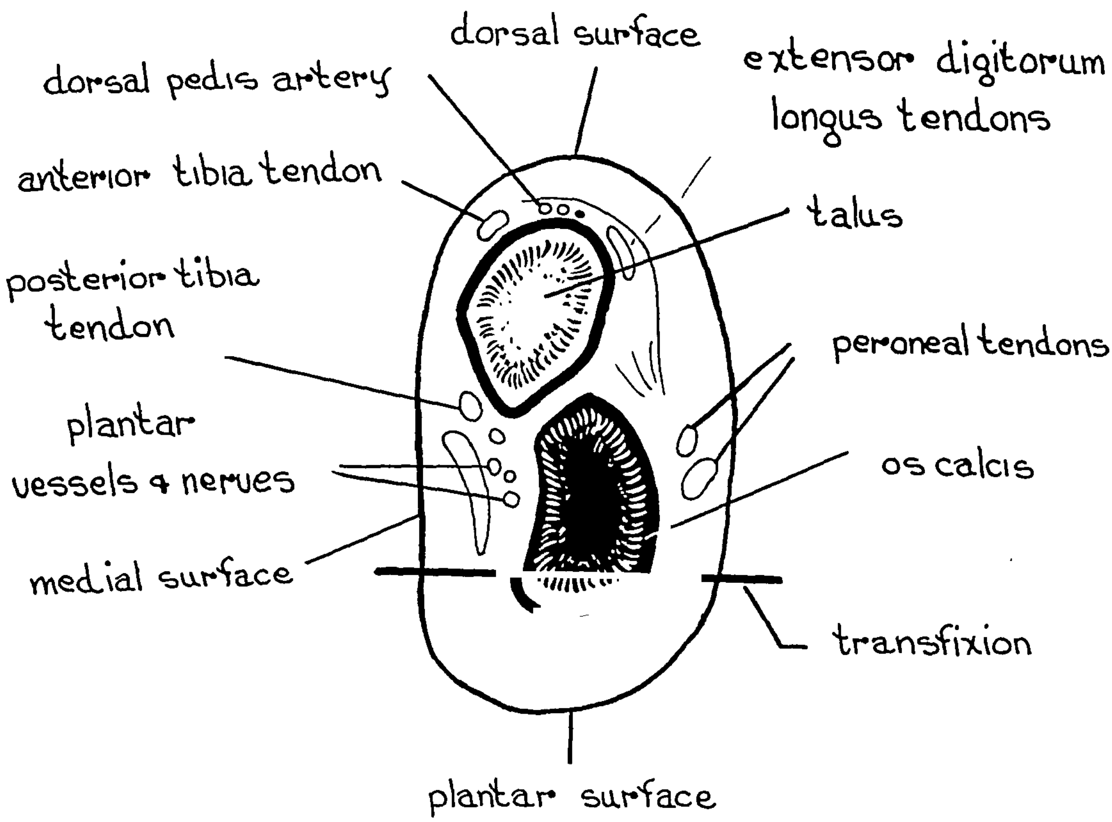


FIG. 7-C

Cross section of the foot made at level *b-b*. Shows the placement of the os calcis transfixion pin.

surfaces, or when the loss of soft tissues prevents closure of the wound, and infection is probable because of the soft-tissue damage, the joint should be arthrodesed immediately by the technique here described, except that the incisions, lengthened if necessary, may be left wide open.

OPERATIVE TECHNIQUE

1. A longitudinal incision is made over the medial malleolus which is then resected subperiosteally. The cartilage and subchondral bone of the talus and the tibia are removed with a curved osteotome.
2. The lateral incision is made as illustrated in Figure 1-B, and the external malleolus is resected subperiosteally.
3. The removal of the remaining cartilage and subchondral bone of the talus and the tibia is then completed.

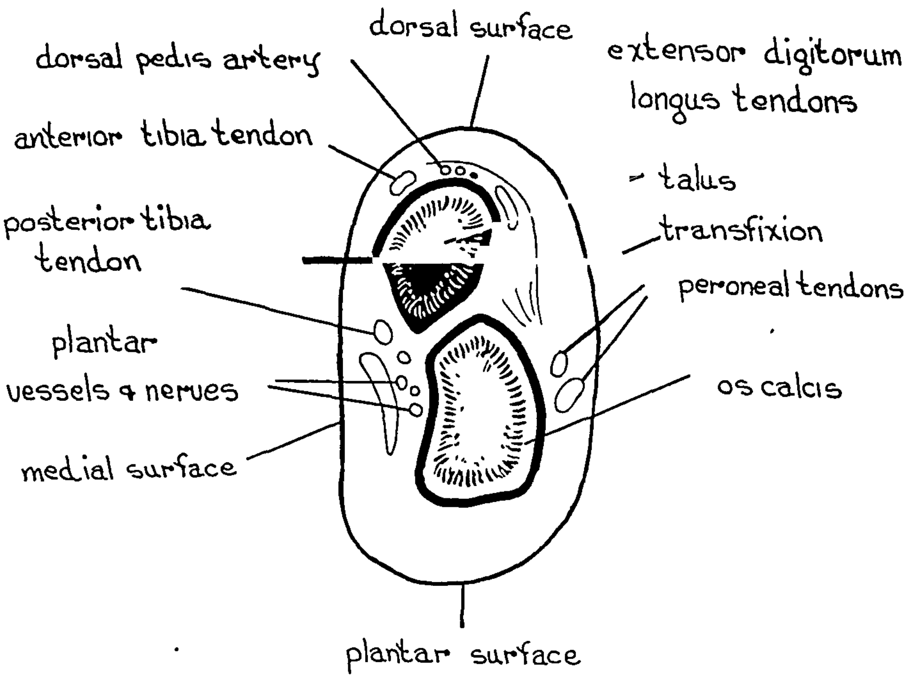


FIG 7-D
Shows the transfixion pin through the talus

In resecting the joint, the osteotome should be held parallel to the tibial or talar articular surface. Care should be taken that all the dense subchondral bone is removed, since union is quicker and surer with cancellous-bone contact. Furthermore, by selecting the angle at which the osteotome is held, correction of a varus or valgus deformity can be

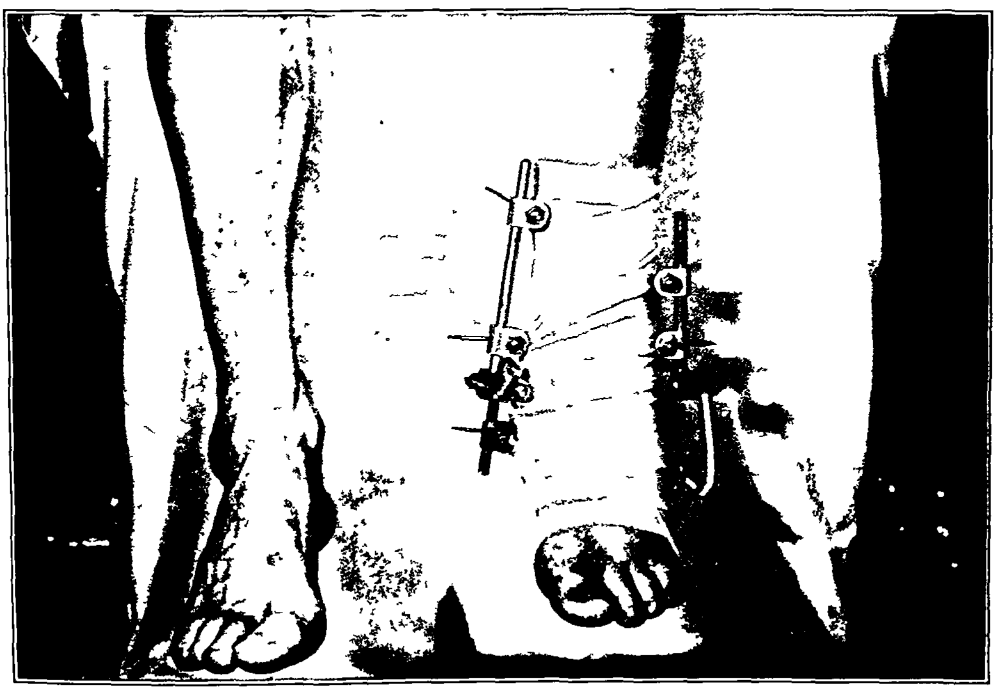


FIG. 8
Mr. B. H., depicting method of castless immobilization An elastic cotton bandage was wrapped around the leg before the fracture units were applied

FIG. 9-A

Mrs. M. W. had been injured one year before the first examination. Even with her weight of nearly 200 pounds, she had been trying to walk. Arthrodesis was performed September 1, 1942.

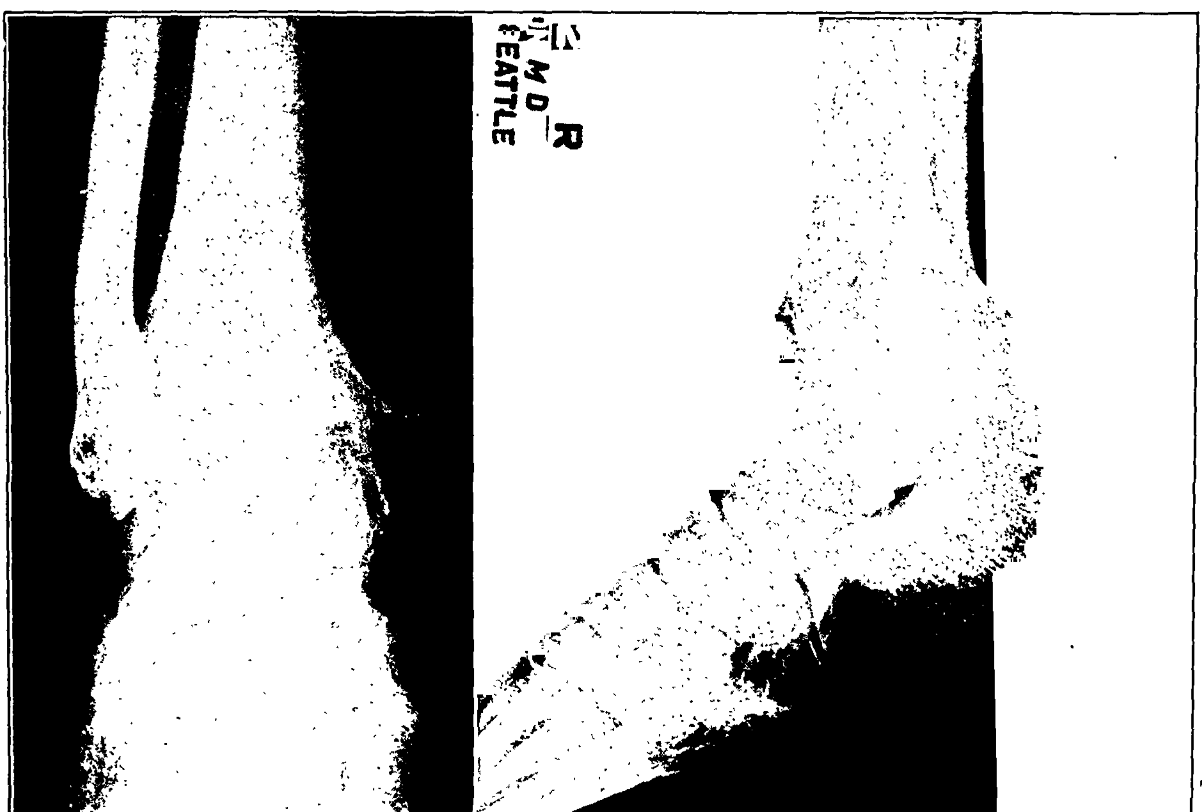


FIG. 9-B

Final roentgenograms taken on February 3, 1944, nearly a year and a half later. Because of her weight, the ankle had been placed in slight valgus. (The author's clinical experience has shown that heavy patients with small feet do better, if the ankle is fixed in slight valgus.)

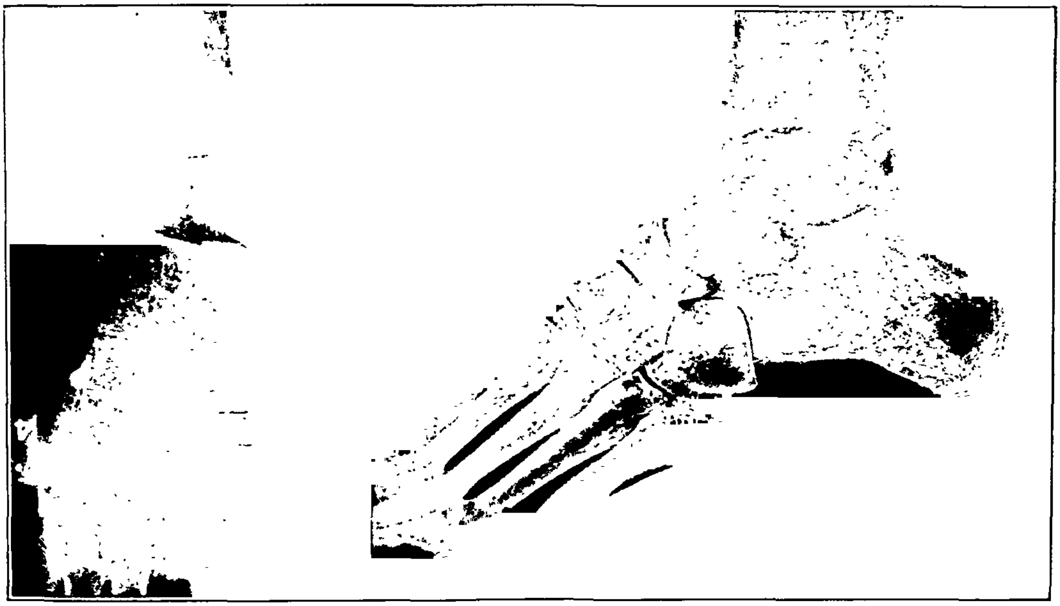


Fig. 10-A

Mrs. R. G., February 12, 1943. A fracture two months before had been treated with adhesive strapping, and the patient had been on crutches most of the time since. The symptoms were out of proportion to roentgenographic findings.

Fig. 10-B

May 4, 1944, fourteen months after operation. Note the formation of the new external malleolus. At this time, the patient walked without a limp.

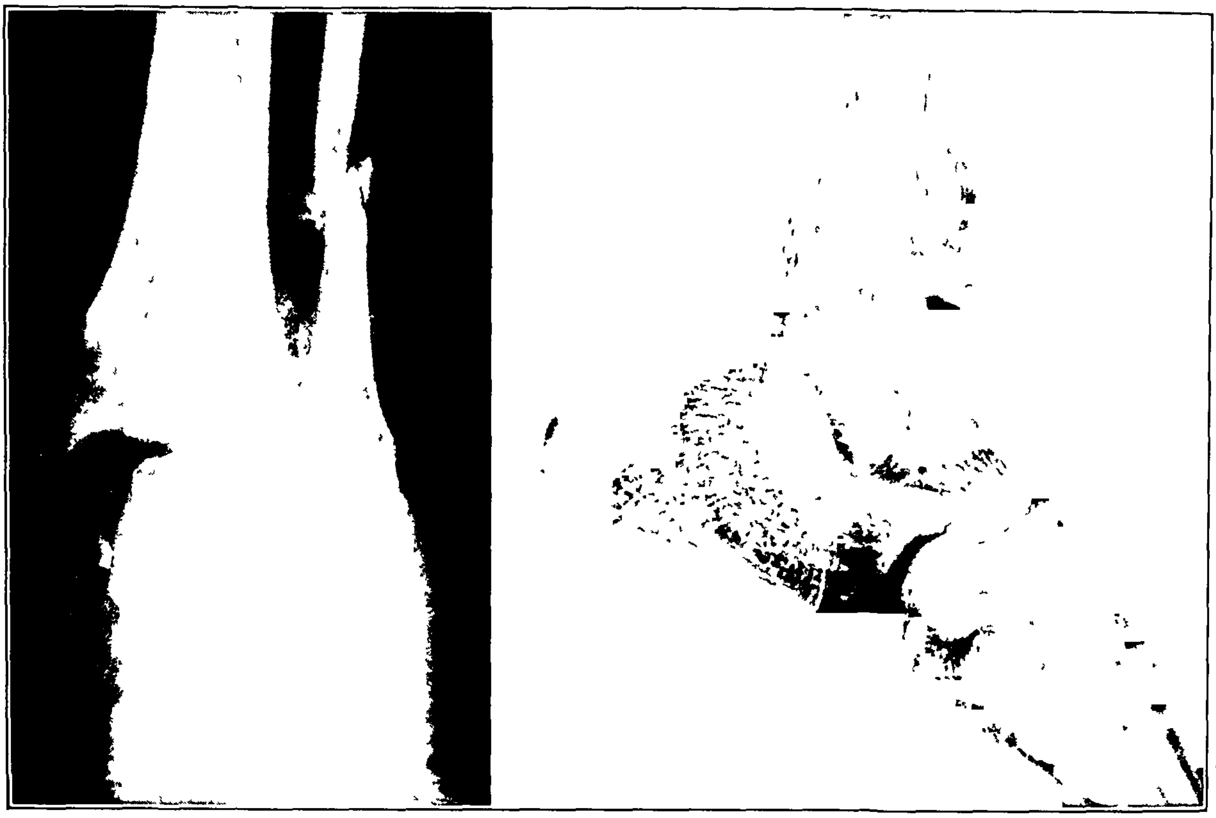


Fig. 11-A

Mr. K. P., September 6, 1943, a month after the accident. He had been treated elsewhere for the extensive, compound fracture-dislocation of the ankle, severance of the tendons, and very deep soft-tissue injury, with large third-degree gasoline burns. When he was referred to us, there was marked infection, and the reduction could not be maintained.

The joint was resected through the large, open, compound wound on the medial side, and several inches of the flexor hallucis longus, flexor digitorum longus, and posterior tibial tendon was resected. The lateral incision was left open, so as to supply through-and-through drainage. The wounds healed, in spite of a large area (several inches in diameter) of persistent skin defect.

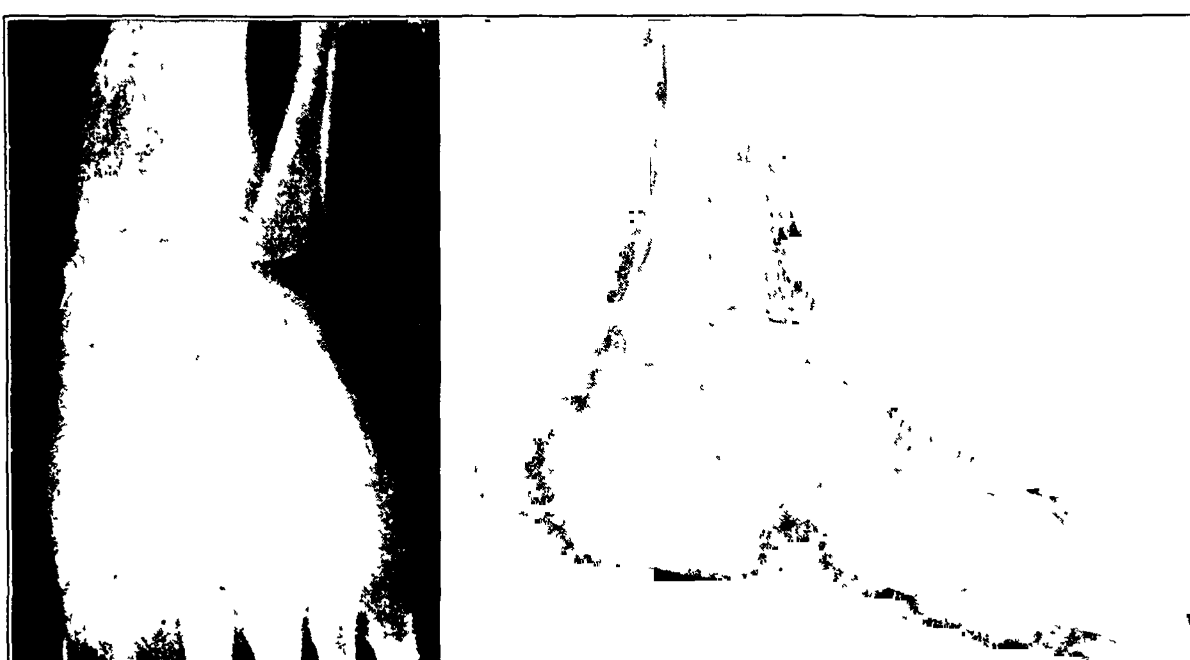


Fig. 11-B

March 22, 1944, six months later. As occasionally happens, when there is an active infection, the roentgenograms reveal only fibrous fusion. However, clinically, there is union. Although it is desirable to fuse the ankle in a position of slight valgus, there is a little too much valgus in this case. This will be corrected when a subtalar fusion is performed after the patienth as recovered from a skin-grafting operation on the medial side of the leg, which was performed May 3, 1944.

Fig. 12-A

Fig. 12-B

Fig. 12-C

Fig. 12-A: Mrs. A. B., aged fifty-four years, sustained a compound fracture-dislocation. A good reduction had been obtained elsewhere on June 28, 1942, but the cast had failed to hold the fragments. On first examination (July 8, 1942), there was dislocation and a large amount of discharge.

Roentgenogram taken on August 15, 1942, revealed soft-tissue swelling and osteomyelitis of the malleoli, talus, and a large portion of the tibia. The fibula had not united and showed no evidence of callus formation. An operation was performed on August 20, 1942, in the presence of a profusely discharging wound and interosseous abscess formation.

Fig. 12-B: Lateral view following operation. There was so much infection and involvement of the soft tissues around the ankle that the transfixion pin anchoring the cast was inserted through the superior tibia. The necessity of resecting so much infected bone resulted in some shortening, and a

(Fig. 12-B *continued*)

greater degree of equinus than illustrated is called for. The desired equinus was subsequently obtained, as shown in Fig. 12-C.

Fig. 12-C: April 10, 1944, nearly twenty months after operation. In spite of the open and grossly infected ankle joint at the time of operation, bony ankylosis has resulted; the fibula has now united; and the wounds have remained healed for nearly a year.

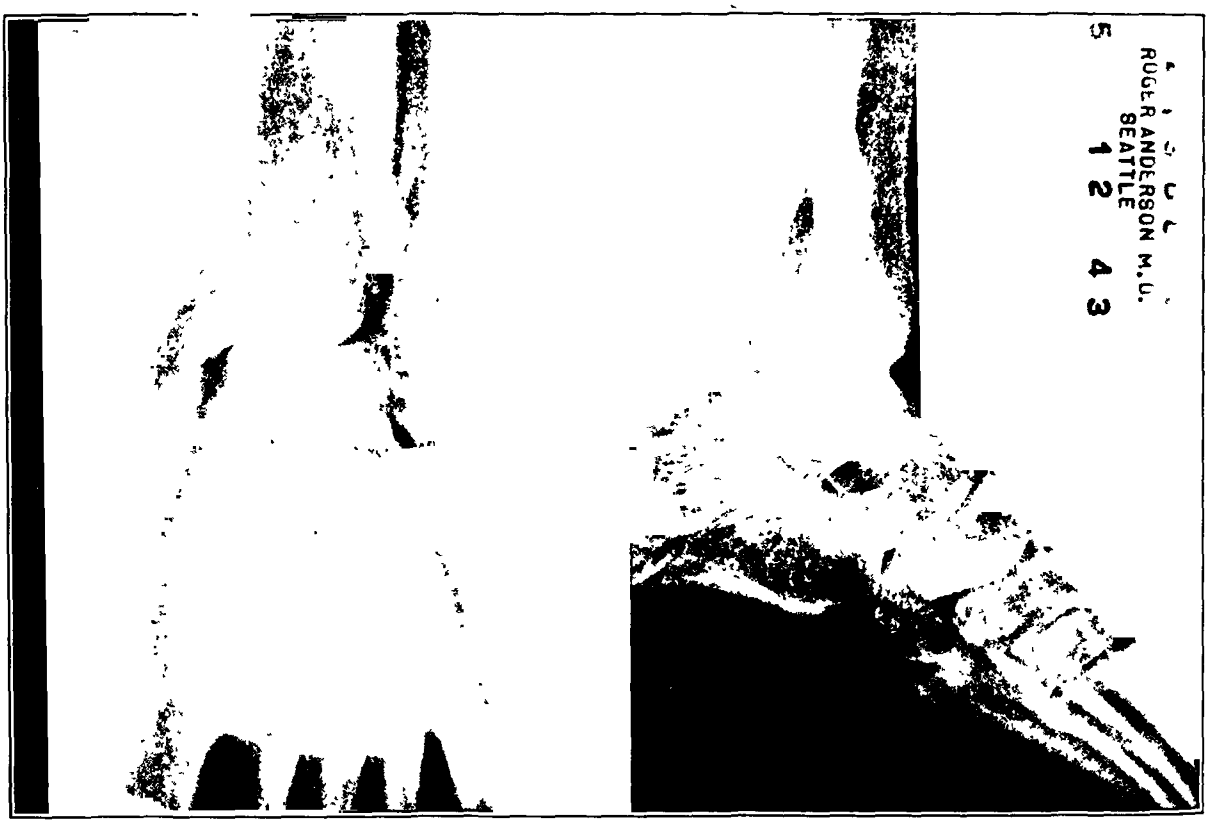


Fig. 13-A

Mr. S. A., May 12, 1943, nearly two years after injury. The patient had sustained an extensive fracture, which had been satisfactorily reduced elsewhere. However, symptoms developed, and his doctor performed an arthrodesis through the usual anterior approach. The roentgenograms reveal that fusion did not result.

readily achieved. Before closure, a close study must be made to be sure that there is no varus or valgus angulation as the talus contacts the tibia.

4. Through the lateral incision, the adjacent surfaces of the tibia and fibula are exposed anteriorly, and are denuded by removing intervening tissue; the resulting space is filled with bone chips obtained from the shafts, so that synostosis will result.

5. The remaining portion of the base of each malleolus is rounded. To stimulate early osteogenesis, little flaps of bone may be raised with a small osteotome from the contiguous surfaces of both tibia and talus. Contact and position are checked and altered as required. The resected malleoli may be cut into small pieces and placed as reinforcing grafts.

6. A fifteen-centimeter (6-inch) Steinmann pin, 0.3 of a centimeter (1/8 of an inch) in diameter (or Kirschner wire with tautener), is placed through the distal tibia at a level approximately five centimeters superior to the ankle joint. Small dry dressings are applied over the pin, and narrow, sterile sheet wadding is used to hold the dressings. A lock nut is attached to each end of the pin to facilitate firmer incorporation in the cast.

7. The cast is applied from toes to below the knee, incorporating the pin.

IMMOBILIZATION

By either the cast or castless techniques, such complete immobilization of the ankle joint is supplied that patients without compound fractures may be crutch-ambulatory.

FIG. 13-B

June 21, 1943. Arthrodesis by the method described was performed on May 22, 1943. The castless technique was employed, with a plaster bandage over the fixation rods to hold the dressings in place.

FIG. 13-C

March 31, 1944, ten months after operation. Roentgenographically there does not appear to be a solid bony union. The patient was complaining of pain in the subtalar joint, and on May 24, 1944, this joint was resected and fused. The ankle joint was exposed through the same incision, and it was found that union was solid between the talus and the tibia. There was slight motion at the tibiofibular junction which had not been surgically fused previously. It was fused at the second operation.

Plaster fixation calls for insertion of one transfixion pin, either through the distal tibia just above the incision or through the superior tibia. The circular cast extend from below the knee to the toes, and in it the pin is incorporated. As the cast is bein applied, pressure is uniformly exerted on the sole of the foot, and the convex talus is presse into the concave tibia for maximum apposition. Immediately after the plaster sets roentgenograms will indicate any needed correction, which may be made at once, or if th position is fair, may be postponed until the stitches are removed.

Castless immobilization is obtained by placing two transfixion pins (or Kirschner wires through the distal tibia, one through the os calcis, and one through the neck of the talus The four pins are then connected with fixation rods, while the talus is being forced int contact with the tibia. The talus and other tarsal bones do not tolerate transfixion pin well, especially if they are not firmly fixed or if there is some loss of bone salts from dis use. Therefore, this is not advocated as a routine procedure; when it is used, it may b advisable to use some plaster or plastic bandages as additional reinforcement.

The transfixion pins should be placed exactly as indicated, but, if the skin in th region of the ankle is scarred or unhealthy, or if a sinus is still present, the tibial trans fixion pin may be placed through the superior tibia.

COMMENTS

The skin incisions should be placed as illustrated, so as not to interfere with th subsequent placement of the transfixion pins.

All efforts should be made to keep the foot in 5 to 8 degrees equinus and in sligh valgus. If postoperative roentgenograms reveal loss of apposition, correction can b secured by removing a thin transverse section of the cast at the level of the ankle an forcing the bones together.

Early ambulation, with active knee and toe motions, is of paramount importance since prolonged immobilization invites phlebitis, muscle and bone atrophy, and diminishe blood supply.

In growing children, the transmalleolar approach supplies a practical route for resec tion of the ankle joint without injury to the epiphyses.

SUMMARY

The transmalleolar approach to the ankle joint, with excision of the malleoli, provide surgical access to the entire joint under direct vision.

Resection of the joint with an osteotome, the curve of which conforms to the arc of th ankle joint, assures an exact osseous approximation, regardless of the degree of equinus

Subperiosteal resection of the malleoli permits direct contact between the talus an the tibia.

Resection of the malleoli and the rounding of their bases make a narrow and shapel ankle.

Bilateral incisions supply a means of obtaining simultaneously drainage of the join and fusion in septic compound fractures, even in the active stage of infection.

Immobilization by means of transfixion pins (or Kirschner wires), fixed by either th cast or castless methods, is so positive and complete that early crutch ambulation can b permitted with safety.

ARTHRODESIS OF THE ANKLE JOINT FOR OLD PAINFUL FRACTURES *

BY HALFORD HALLOCK, M.D., NEW YORK, N. Y.

From the New York Orthopaedic Dispensary and Hospital, New York

Arthrodesis is an effective means of relieving the pain and disability that often arise from old ankle fractures. This fact is established by an end-result study of thirty-eight of the forty-seven patients who had an ankle fusion for this condition at the New York Orthopaedic Hospital from January 1928 to April 1943. Nine of the forty-seven had follow-up examinations less than one year after operation, and have therefore been excluded from the end-result group. They are included, however, in the preoperative and operative study. One patient had bilateral arthrodesis, making a total of forty-eight ankle fusions. Twenty-two of these cases were reported by Kimberley in 1936.[1]

This is not a large number of cases for a period of fifteen years. Many more patients than this were seen in the Dispensary complaining of painful ankles following fractures, 216 in the five-year period from 1928 to 1933, according to Kimberley; but, in many, conservative measures probably afforded sufficient relief, and, in some, surgery was undoubtedly not accepted when advised.

The group of patients operated upon, therefore, represents the more severe type of case, or the one in which conservative measures have failed. The pathological changes seen in these joints at operation make the surgeon appreciate the potentialities of surgery, and the limitations of physical therapy and support. Better treatment of the original fracture will probably mean less need for subsequent treatment or surgery; but even with accurate anatomical reductions, which can be secured in most instances only by meticulous open reduction, defects of the articular surface may persist, and a painful arthritis may ensue.

All but three of the forty-seven patients who were operated upon had more or less severe malunited fractures affecting the ankle joint; and in these three, although their fractures had healed in good alignment, a pronounced arthritis had developed. One had additional deformity caused by partial epiphyseal arrest, brought about by the original injury.

The patients complained chiefly of pain and limitation of function. Their ages at the time of operation ranged from sixteen to fifty-six years; the average age was thirty-eight; the time of operation after the original injury varied from one month to twenty-one years; the average time was three and seven-tenths years. One patient, whose ankle was fused one month after fracture, had sustained multiple injuries in a thirty-five-foot fall, including a comminuted fracture of the distal fourth of the tibia involving the ankle joint, with a forward and upward dislocation of the talus. It was obvious that no treatment other than an arthrodesis would yield a satisfactory result. Fusion was obtained within six months, and at the last examination, three years later, the patient was free from pain and walked normally with or without shoes.

OPERATIVE TECHNIQUE

The ankle joint is exposed through an anterior longitudinal incision midway between the malleoli. A tourniquet is used above the knee. The tendons of the extensor digitorum longus are retracted laterally and those of the tibialis anterior and extensor hallucis longus, together with the dorsalis pedis vessels, are retracted medially. The periosteum of the tibia and the capsule of the ankle joint are divided longitudinally, and are reflected

* Read at the Annual Meeting of The American Orthopaedic Association, Hot Springs, Virginia, June 1, 1944.

sufficiently to expose the anterior borders of both malleoli and their articulations with the sides of the talus. The articular cartilage is removed from the superior, medial, and lateral surfaces of the talus, from the tibia, and from both malleoli. Mild or moderate degrees of deformity can now be corrected by removing certain portions of bone. Sometimes it is also necessary to perform osteotomies of the malleolar portions of the tibia and

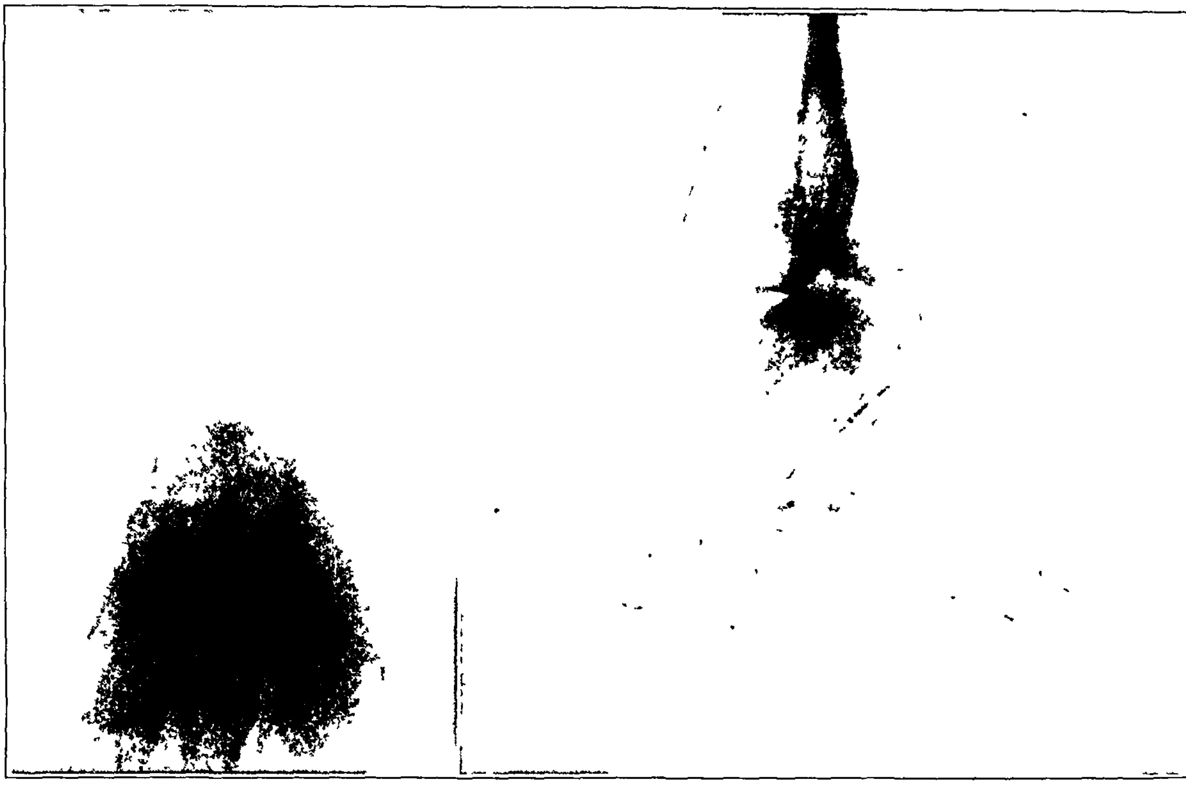


Fig. 1-A

A. McG. Preoperative condition four months after fracture.

Fig. 1-B

Ten years after ankle fusion. There is no pain, and patient can be on her feet all day and walk as far as she pleases. The ankle is fused in 10 degrees of equinus.

FIG. 2-A

H. F. Preoperative condition fifteen months after fracture Subtalar arthritis is present.

FIG. 2-B

Eight years after ankle fusion. Subtalar arthritis is more marked. There is fatigue in the foot and the ankle after walking ten blocks, and pain in bad weather Subtalar joint mobility is limited two-thirds by stiffness

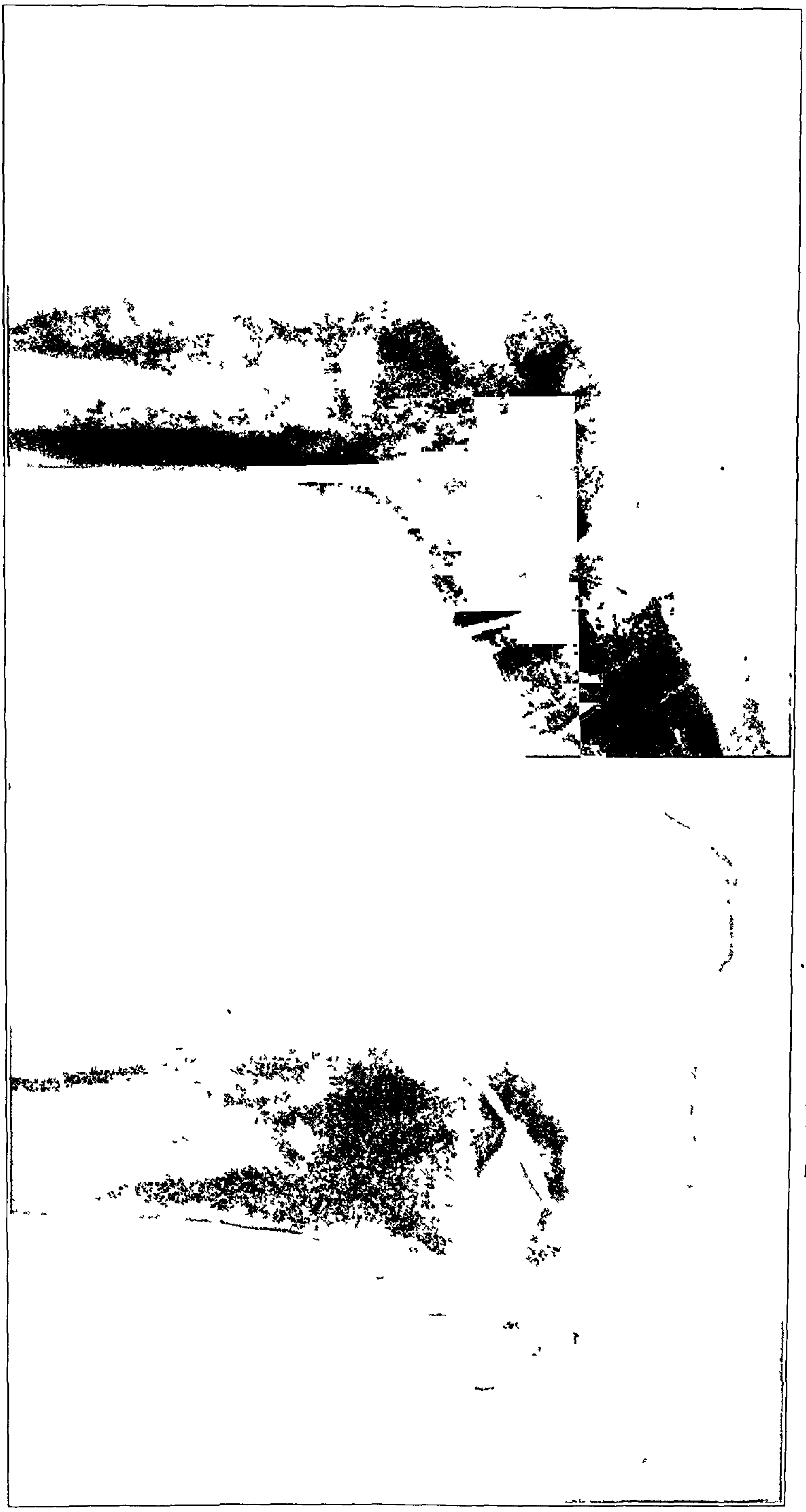


Fig. 3-A

Fig. 3-B

Fig. 3-A: S. C. Subtalar and talonavicular arthritis two years after ankle fusion. This was present before operation but not quite so marked.
Fig. 3-B: Seven years after triple arthrodesis because of pain. Lipping is now present dorsally at the cuneonavicular joint. Patient has been relieved of most of her preoperative pain and is on her feet all day, doing housework and cooking.

fibula or of the lower portion of the fibula, in order to obtain adequate correction and to restore the foot to a proper weight-bearing alignment with the leg. Occasionally lengthening of the tendo calcaneus may be required to aid in correcting equinus.

The opposing bony surfaces are then "fish-scaled" by turning down attached chips of bone and interlacing them, if possible, across the joint interval. Additional bone chips are removed from the lower portion of the tibia and are packed into the spaces between the talus and the tibia, and the talus and both malleoli. Chips are also laid across the joint anteriorly. (In five patients, bone grafts or pegs were employed as well.) The wound is closed in layers, and after the deep sutures have been placed, the tourniquet is removed. A plaster cast is applied, extending above the semiflexed knee, with the foot in 10 degrees of equinus.

A plaster boot for walking is applied after six weeks, and usually the arthrodesis is strong enough to bear weight without support after twelve weeks. Once the cast has been removed, physical therapy is employed to decrease swelling, to rehabilitate the muscles, and to promote compensatory mobility in the subtalar and tarsal joints. If arch strain occurs, a support may be used for as long a time as is necessary.

The position of the ankle is checked by roentgenograms after operation. The degree of equinus is determined by drawing a line from the inferior surface of the calcaneus to the plantar margin of the first metatarsal head, and a second line through the longitudinal axis of the tibia, and measuring the angle of their intersection. If the position is not satisfactory, the cast is cut posteriorly above the heel, a section is removed over the ankle joint anteriorly, and the foot is brought up to the proper position. If the ankle is to be wedged downward, the section of plaster is removed posteriorly. This should be done, when necessary, five to ten days after operation. One or two wedgings do not seem to interfere with fusion, but it is conceivable that more might do so.

OPTIMUM POSITION FOR FUSION

An equinus of about 10 degrees is considered generally to be the best position for a fused ankle, as with this amount and with the range of compensatory mobility that usually develops in the subtalar and tarsal joints, walking is easy and essentially normal with or without shoes. When an ankle is fused at right angles or less, difficulty is experienced in advancing over the foot, and an undesirable and awkward heel gait results. With more than 15 degrees of equinus, increased stress and strain is brought to bear upon the metatarsal region, and barefoot walking becomes more and more difficult. Weight is borne either entirely on the ball of the foot, or on the heel and sole by external rotation and abduction of the hip, and hyperextension of the knee. With shoes on, however, a patient with excessive equinus may not exhibit an abnormal gait, because of the compensating effect of a high heel.

CORRECTION OF LATERAL DEFORMITY

If lateral deformity of the ankle is present to a degree sufficient to alter considerably the weight-bearing line through the leg and foot, correction should be obtained. In mild or moderate degree, this can be accomplished by the removal of appropriate wedges of bone with or without malleolar osteotomies; but when the deformity is severe, it is probably better to fuse the ankle in the deformed position, and then later to do an osteotomy of the tibia and fibula through the cancellous bone above the joint. At this level, the fragments are controlled fairly easily, and there is less danger of delayed union or non-union than when the bones are divided at a higher point. Supramalleolar osteotomy was not done in this series; but, on several occasions, it has been performed, without fusion, to correct deformities of the lower end of the tibia without other ankle-joint disorder; and, in one case, with joint involvement, prior to probable fusion. This osteotomy was planned for in one case, to follow arthrodesis, but has not been performed,

because the patient has done well following fusion alone, and apparently has compensated adequately for the malposition.

An attempt to correct the lateral deformity at the time of fusion was made in fourteen, or 29.2 per cent., of the forty-eight ankles. This was not always successful, and often correction was found to be difficult and sometimes impossible. For this reason, it would be well to study carefully cases with marked deformity, from the point of view of obtaining proper alignment after fusion by supramalleolar osteotomy.

COMPLICATIONS

Complications were few in number. There were no deaths from operation. One patient died from a cardiac condition four years after operation. A pressure ulcer developed over the medial malleolus in one patient, a hematoma developed in another, and maceration of the wound occurred in two.

There were three wounds infected with the staphylococcus aureus. One was superficial and healed readily.

In the second case, the infection involved the ankle joint, and extended into the talonavicular joint, with resultant ankylosis of that articulation. This patient had had a compound fracture one and a half years before, with drainage for seven months. Now, three years later, he has a clinically fused ankle in 10 degrees of equinus, and a stiff foot in mild varus. He is on his feet at work all day. There is no drainage, but occasionally he has pain in the foot at the end of the day.

In the third case, infection occurred after a refusion of the ankle. Eventually a sequestrectomy was necessary, and the most recent roentgenogram does not show bony union. The ankle, however, is solid clinically, and there is no drainage.

RESULTS

Thirty-eight of the forty-seven patients have had follow-up examinations from one to sixteen years after operation. The average time was four and four-tenths years. As one individual had bilateral fusion, thirty-nine operations are represented in this end-result group.

Arthrodesis

Bony union was secured in thirty cases, or 77 per cent.

Failure of fusion definitely occurred in four. This is a known failure of 10 per cent. Three of these patients have been reoperated upon, with success in one, failure in another, and a doubtful result in the third. The last was the patient in whom an infection developed at reoperation. The fourth patient has been advised to have another operation, but has declined, although she is having pain.

In five patients, or 13 per cent., arthrodesis may be doubtful. In two of these, final roentgenograms at nine months did not demonstrate fusion; but arthrodesis is clinically present three and four years later, and symptoms are absent except for occasional pain at the end of the day in one. In three patients, roentgenograms at thirteen months, fourteen months, and three years, respectively, revealed doubtful fusion. It may be present, however, as these three individuals are free from pain and have clinically solid ankles.

If these five cases in which the presence of fusion might be questioned are added to the four in which arthrodesis did not occur, a possible failure of 23 per cent. is obtained.

Pain

All the patients except one had pain preoperatively to such a degree as to cause disability and to force them to accept surgery for its relief.

Postoperatively, twenty-two, or 56.4 per cent., are completely free from pain; eight, or 20.5 per cent., occasionally complain of slight pain in the foot or ankle (as at the end of

a long day or in bad weather); and eight, or 20.5 per cent., have considerable pain. In one patient, no note was made with regard to symptoms; but the roentgenogram reveals a doubtful fusion, and it is possible that this patient may be having pain, although the ankle feels solid clinically.

Adding the first two groups, thirty ankles, or 76.9 per cent., have been completely or almost completely relieved of pain.

The patients who are complaining of pain have been studied in an effort to discover the reasons for the persistent symptoms. In three of the eight, who occasionally have slight pain, no apparent cause has been found; late roentgenograms in two cases are not

FIG. 4-A

W. D. Preoperative condition one year after fracture.

FIG. 4-B

Three years after operation. Fusion is doubtful roentgenographically, but may be present through a small area posteriorly. Patient is free from pain and is on his feet all day.

FIG. 5
Illustrating the use of supramalleolar osteotomy in the correction of ankle varus.

available; while in the third, the roentgenogram showed a doubtful fusion thirteen months after operation, but clinically, arthrodesis is present three years later. Excessive equinus of 19 and 22 degrees may be a factor in two patients, because of induced strain. In two, the roentgenograms reveal arthritic changes at the talocalcaneal joint in one, and at the cuneonavicular articulation in the other. In the eighth patient, the foot is stiff and in mild varus, with ankylosis of the talonavicular joint following postoperative infection.

In the group of eight individuals who are having considerable pain, failure of fusion is present in one, and probably in another. The fibular malleolus in one case did not unite with the talus, and an arthritic reaction has occurred at this point, as revealed by roentgenograms. Although the ankle is fused, no other cause has been found for the pain, which is referred to the anterolateral aspect of the joint. Refusion of the lateral talomalleolar joint has been advised. One patient has residual varus, following incomplete correction of a marked degree of deformity; and another, who had a triple arthrodesis for arthritis of the talocalcaneal joint, apparently has a non-union of the subtalar articulation. In two patients, subtalar arthritis is probably present. In another, roentgenograms show considerable arthritic reaction in the talocalcaneal and talonavicular articulations; triple arthrodesis has been advised, but has been declined, as the patient considers that she is not having sufficient pain at present to warrant the operation.

The chief causes, therefore, of persistent pain appear to be failure of fusion of an arthrodesed joint, varus, or excessive equinus, and concomitant subtalar or tarsal arthritis.

Limp

The presence or absence of limp has not been recorded in ten of the patients. In the remaining twenty-eight, when walking with shoes, a limp was absent in twenty-four, or 85.7 per cent., and present in four, or 14.3 per cent. In the four, the limp appears to be due to arthritis of the subtalar joint in one; probable lack of fusion of the talocalcaneal joint following triple arthrodesis for arthritis in another; poor shoes and a pantalar arthro-

desis in a third; and probable failure of fusion at the right ankle and subtalar arthritis on the left in the fourth, the one bilateral case. Without shoes, limping is more frequent, especially in those in whom the amount of equinus exceeds 15 degrees.

The use of a heel of correct height for the degree of equinus, and the development of compensatory mobility in the subtalar and tarsal articulations are the chief factors in promoting a normal gait in the presence of a fused ankle. Every effort should be made to secure the position of 10 degrees of equinus, because this amount affords facility of walking with or without shoes.

SUBTALAR AND TARSAL ARTHRITIS

Subtalar or tarsal arthritis was revealed roentgenographically in eight of the patients before operation, and in four others after operation. This constitutes 25 per cent. of the whole group of forty-eight ankles. The talocalcaneal articulation was involved preoperatively in six patients, postoperatively in four; the mediotarsal joint, preoperatively in three patients, postoperatively in one; the cuneonavicular articulation, preoperatively in none, postoperatively in one. The mediotarsal arthritis in one patient was associated with a pseudarthrosis which had resulted from an operation performed a number of years earlier to correct forefoot equinus following the original injury.

The degree of arthritis varied considerably, and ranged from marked articular change to mild thinning of the joint space or slight lipping at the articular margins.

To control this complicating condition, a subtalar or triple arthrodesis was performed in five of the twelve patients, while a talocalcaneal fusion was done in one, and a refusion of the mediotarsal joint in another. Both of these latter procedures were performed at the same time as the ankle fusion. In the remaining five patients, no further surgery has been done, but subtalar arthrodesis has been advised in at least one. Two of the five are having considerable pain; two, mild discomfort at times, and one is free from symptoms. The roentgenograms in this case, made before operation, showed only slight lipping posteriorly at the talocalcaneal joint; no further roentgenograms have been taken since the cast was removed, at which time fusion was demonstrated to be present. Clinically, tarsal mobility is good.

The presence of a concomitant subtalar or tarsal arthritis must always be considered in the examination and study of these cases, as it may be a major factor in the subsequent function of the foot. Usually, it is probably related to the original trauma; but it can develop after operation as it did in four patients of this series.

Arthritis in mild degree should be treated with support and physical therapy; but when it is present to a considerable or marked degree, either subtalar or triple arthrodesis should be done, or the patient should be informed of its presence and of the possible necessity for further surgery later on.

1. Kimberley, A. G.: Malunited Fractures Affecting the Ankle Joint. With Special Reference to Twenty-Two Cases Treated by Arthrodesis. Surg. Gynec. Obstet., LXII, 79, 1936.

DISCUSSION

Dr. H. R. Conn, Akron, Ohio: We are indebted to Dr. Hallock for calling our attention to this tibiotalar fusion which in my opinion is not used as widely as it might be. It is applicable to any lesion that produces a disintegration of the articular elements.

As has been observed, compensatory hypermobility of the mid-tarsal joints very quickly develops in these patients, and as a result they suffer less functional disability than might be anticipated.

About ten years ago I showed nine of these patients with fusions to the Ohio State Medical Society. All had had arthrodesis long enough for the maximum degree of hypermobility to develop, and I was not surprised when members of the audience insisted that no true tibiotalar fusion existed. Of course the roentgenograms were available to prove that solid bony fusion was present between the tibia and the talus.

In the early cases, I attempted joint excision and the implantation of chips, but I have had much better results with a sliding bone graft plus chips.

I would re-emphasize the value of this operation and the surprising lack of disability which results.

DR. J. WARREN WHITE, GREENVILLE, SOUTH CAROLINA: I think we are gradually doing more and more of these operations because they are so very satisfactory. There is one little device that I have used which is really a part of the postoperative dressing. I will show it on the board. It concerns the holding of the parts together. You will remember some years ago Key emphasized the importance of positive pressure in stabilizing knees. Why not use the same principle in the ankle? I put one stainless-steel pin, one-eighth of an inch thick, just above the location of the epiphyseal line and another one through the lower posterior portion of the os calcis so that the vessels will be missed. After applying the dressing, I attach rubber bands between these two pins.

This makes it unnecessary to extend the cast above the knee. It stabilizes the entire lower leg satisfactorily. I have treated four of these cases in this way. The extreme pressure from the bands is exerted only while the plaster is hardening, which prevents any serious amount of pressure necrosis (Fig. A).

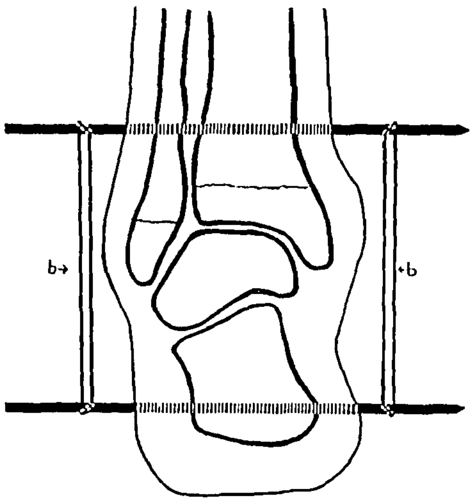


FIG. A
b: Rubber bands.

DR. J. ALBERT KEY, ST. LOUIS, MISSOURI: Many of these patients have a diastasis with a broad ankle which is undesirable. Also, the objection to the arthrodesis from the front is that, as you take the cartilage off, you narrow the talus and widen the mortise. The more you take off, the worse it fits. I now remove the articular cartilage from the front, and slide a cortical graft from the tibia down through a window or tunnel in the lower end of the tibia into the body of the talus. Then, through a lateral incision, the external malleolus is cut across, driven inward to narrow the mortise, and fixed with a long oblique screw. This gives a neater looking ankle, and it fuses more rapidly.

DR. W. E. GALLIE, TORONTO, ONTARIO, CANADA: I want to add a word of support to what Dr. Hallock and Dr. Conn have said. It has been my experience that when the ankle joint has been solidly ankylosed in good position, the patient is relieved of his symptoms and is enabled to walk practically normally.

As they have pointed out, however, there are complications which are serious. The 6 per cent. infection rate and the 20 per cent. failure of arthrodesis are too high to justify complacency. It has seemed to me that the probable explanation of the high infection rate is that the operation is rather prolonged and is severely traumatizing. The failures of arthrodesis are undoubtedly due to imperfection in fitting the raw surfaces of the bones together, or to defective immobilization. To reduce the frequency of these complications, we should try to reduce the extensiveness of the operation, and at the same time make use of more perfect contact of bone surfaces. These requisites may perhaps be found in the method I described some years ago for arthrodesis of the subtalar joint. In this, the arthrodesis was brought about by mortising bone grafts into the talus and os calcis without removing the articular cartilages. In the ankle, the same principle can be employed by removing the articular cartilage from the malleoli and the body of the talus, and by filling the spaces so produced with tightly fitting bone grafts. Additional security may be obtained by sliding a graft down from the anterior aspect of the tibia across the joint line into the neck of the talus.

The number of patients treated in this way has not been great enough to justify any statement as to final results. To date, however, we have operated upon ten patients, and bony union has occurred in all. The operation has the additional advantage that, because the articular cartilage between the tibia and talus has not been removed, no shortening occurs, and there is no additional deformity. In women, this is of particular importance.

DR. HALFORD HALLOCK, NEW YORK, N. Y. (closing): I appreciate very much the discussion. We have not used internal fixation at the Orthopaedic Hospital except in a spastic patient. Two vitallium screws were used in one patient. We have felt that internal fixation was not necessary, and we have obtained a high percentage of bony union. The elastic pressure which Dr. White spoke of may be helpful in obtaining compression at the arthrodesed joint, and, if that pressure is not so great as to cause pain and discomfort, it will probably help in initiating bony union. In connection with this, he stated that it would not be necessary to extend the plaster above the knee; but even with the pins as he has shown in his diagram, it seems impossible to prevent some anteroposterior motion at the ankle joint, because of the calf muscles which in part arise above the knee joint. It might be better to use plaster above the knee for a short period of time.

In answer to Dr. Gallie's discussion, I would like to say that his method, with fusion occurring in six months' time, seems to be useful in the ankle without deformity. When deformity is present, however, more would have to be done to obtain a good-looking ankle. Our casts have been taken off in twelve weeks. In 90 per cent. of the cases, fusion has been strong enough in twelve weeks to permit the patient to go without a cast. I think that fact justifies the use of this type of operation to obtain early fusion.

EXPERIMENTAL PRODUCTION OF SCOLIOSIS IN RATS AND MICE

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A satisfactory understanding of the mechanism involved in the production of scoliosis in man is yet to be fully reached. One means toward this end has been to create this condition deliberately in laboratory animals by various methods.

Wullstein, in 1902, produced permanent scoliosis in dogs by strapping the animals in a position of lateral deviation for a long period of time; Carey, in 1932, produced scoliosis in rats by transplantation of the animals' tails; Bisgard, in 1935, produced scoliosis in animals by "pleural imbalance", producing massive scarring and fibrosis of the chest by surgical means.

Arnd, in 1903, reported the production of scoliosis in rabbits, with associated rotation and wedging of the vertebral bodies, brought about by unilateral excision of the deep back muscles. Carey mentioned the production of experimental scoliosis in animals by muscle excision. Bisgard reported scoliosis due to muscle imbalance produced by resection of the nerves to the intercostal and sacrospinalis muscles.

Pacher, Haas, and Bisgard and Musselman produced scoliosis in animals by surgical means. They partially destroyed the vertebral epiphyseal plates, thereby causing uneven vertebral growth which resulted in lateral deviation of the spine. Engel and Richer likewise produced disturbances in the growth of vertebral bodies by the implantation of radium into the epiphyseal plate, and by this means produced scoliosis experimentally in animals.

Carey demonstrated in a mechanical model that "dynamic equilibrium of the muscle and bone of the back" must be maintained to keep the normal alignment of the vertebral column. He also presented evidence that combinations of muscle groups in balance and in imbalance bear definite and constant influence on normal and abnormal vertebral alignment, respectively.

In the experiments undertaken in this study, the objective has been threefold:

1. To determine the effect on the alignment of the vertebral column of muscle imbalance, produced by unilateral excision of groups of symmetrical muscles which influence the movements and position of the vertebral column.

2. To determine the effect on the alignment of the vertebral column of bilateral excision of groups of symmetrical muscles which influence the movements and position of the vertebral column.

3. To determine the effect on the alignment of the vertebral column of muscle imbalance, brought about by the operative release of the muscles from their attachments to the vertebrae and the prevention of their reattachment by the interposition of inert material between the muscle mass and the vertebra to which it was attached.

MATERIAL AND METHODS

Both rats and mice were used; thus two groups of experiments were carried out.

In Experiment I, twenty-six healthy, young, growing, male rats were used; they averaged five months of age at the beginning of the experiment. The average weight was 300 grams. These animals were not necessarily litter mates.

In Experiment II, seventeen animals of a Swiss-Colony strain of laboratory mice were used. The average age was three months, and the average weight was twenty-three grams. Both sexes were included, but were segregated in order to keep pregnancy from complicating the experimental results.

The anaesthetic used was veterinary solution nembutal. In Experiment I, an average of 0.21 cubic centimeters of solution per 300-gram rat was injected intraperitoneally. In Experiment II, an average of 0.02 cubic centimeters of solution per 23-gram mouse was injected intraperitoneally. Anaesthesia was complete in five to ten minutes, and lasted for a period of from forty-five to sixty minutes.

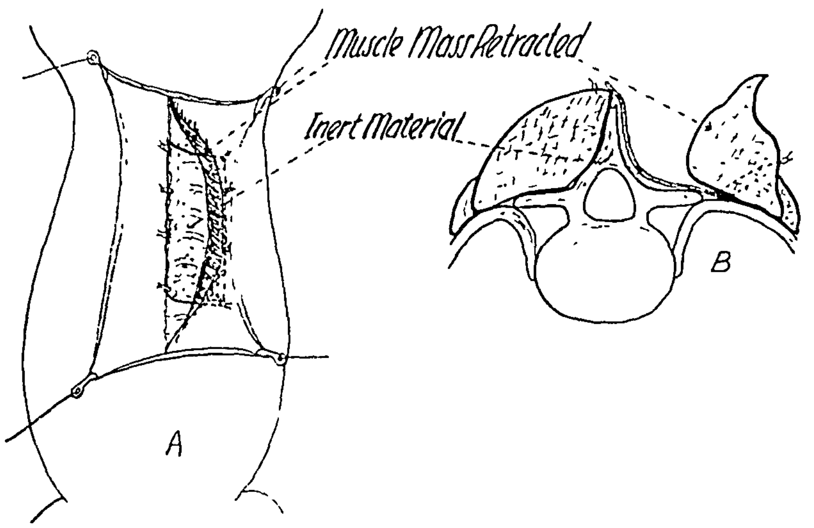

Fig. 1

Showing diagrammatically the method of insertion of inert material after subperiosteal release of muscle mass.

A: Viewed from the operative approach. *B:* Cross section.

The preoperative preparation and postoperative care given to the animals was as follows:

In Experiment I, preoperative preparation consisted in shaving the back from the base of the skull to the mid-lumbar region and for approximately one centimeter on each side of the mid-line. Seventy per cent. alcohol was used as a skin antiseptic; three-minute scrubbing of the hands without the use of surgical gloves, but using sterile instruments, constituted the aseptic precautions. Postoperative care consisted only of allowing the animal free access to water and food, and keeping it in its cage, in a warm room, free from drafts, for nine days.

In Experiment II, preoperative preparation was similar to that given in Experiment I; and the postoperative care was also the same.

The animals used in Experiment II were then exercised regularly in a revolving-drum type of treadmill, as described by Lanier, starting with ten to fifteen minutes daily, and gradually increasing to two hours twice daily, as they were able to tolerate the work. For the most part, the animals had difficulty for about ten days, as they were apparently lame in the extremity on the side operated upon, but after this length of time they seemed able to compensate sufficiently to maintain the gait satisfactorily. Obviously the animals could not be under constant surveillance; often an animal drowned. No wound infections were encountered in any of the animals of either experiment.

The inert substances used were: (a) surgical Penrose rubber drain; (b) commercial cellophane sheets, removed from a given brand of cigarette packages, and sterilized by boiling; and (c) insultoic membrane—chromicized bovine allantois.

EXPERIMENTAL PROCEDURE

Experiment I (Rats)

1. *Unilateral Removal of Superficial and Deep Back Muscles on the Left or Righ (Fourteen Rats).* The skin was incised in the mid-line between the levels of the uppe border of the scapula and the thirteenth rib. The cutaneus maximus was divided in th mid-line in a similar manner, and was retracted laterally, thus allowing exposure of th superficial back muscles. The spinotrapezius was identified, dissected free from its at tachment to the spinous processes and thoracolumbar fascia, dissected to its insertion o the scapula, clamped at its insertion, divided, and removed. The latissimus dorsi wa freed with the thoracolumbar fascia throughout its extent of attachment to the spinou processes, was dissected free to within 0.5 of a centimeter of its insertion into the humerus and was crushed, divided, and removed. This resulted in exposure of the deep bacl muscles. The entire deep muscle mass (the serratus posterior groups) was separate(

from its attachment to the spinous processes, laminae, transverse processes, and ribs between the fourth and thirteenth thoracic vertebrae, inclusive. This muscle group was clamped above and below at the levels of the fourth and thirteenth thoracic vertebrae, respectively, and was removed *en masse* between the clamps. Any residual muscle tissue (such as intrinsic back muscles) was scraped off the laminae, transverse processes, and ribs, and was excised, leaving the bony structures in the operative field exposed subperiosteally. Intercostal musculature was not injured. All clamps were removed, the wound was closed by approximating the cutaneus maximus and skin in their respective layers with interrupted No. 40 black cotton sutures. No dressings were applied. Operative time averaged twenty-five minutes from start to finish. There were no immediate operative deaths. In four of these animals, only the superficial musculature on one side was excised by the procedure described; the deep muscles were not disturbed.

2. *Bilateral Removal of Superficial and Deep Back Muscles (Four Rats).* In the bilateral surgical removal of superficial and deep back muscles, the technique employed on each side was the same as the procedure in the unilateral excision.

3. *Removal of Superficial and Deep Muscles on One Side, and Release of Muscle Attachment to Spinous Processes, Laminae, and Transverse Processes on the Opposite Side, with the Interposition of an Inert Material to Prevent Reattachment (Three Rats).* The technique for removal of muscles on one side has been described. Beyond this point the procedure was altered. On the opposite side, the superficial muscles were released from attachment to the spinous processes; the deep muscle mass was freed from the vertebrae subperiosteally, and was separated by dissection as far laterally as the costal angle. This procedure was carried out through the same extent as that of the muscle excision on the opposite side. After subperiosteal stripping of the deep musculature, a piece of inert material (rubber dam, cellophane, or insultoic membrane) was cut so as to cover exactly the denuded area of the spinous processes, laminae, and rib cage, and this material was sutured in place by interrupted cotton sutures as illustrated. The membrane was sutured across the tips of the spinous processes, and anchored to the interspinous ligaments (Fig. 1). Wounds were closed as already described. In three additional animals, unilateral release of muscle attachment was maintained by interposition of an inert material as described above, but in these animals the opposing muscle group was left undisturbed.

Two animals were used as controls.

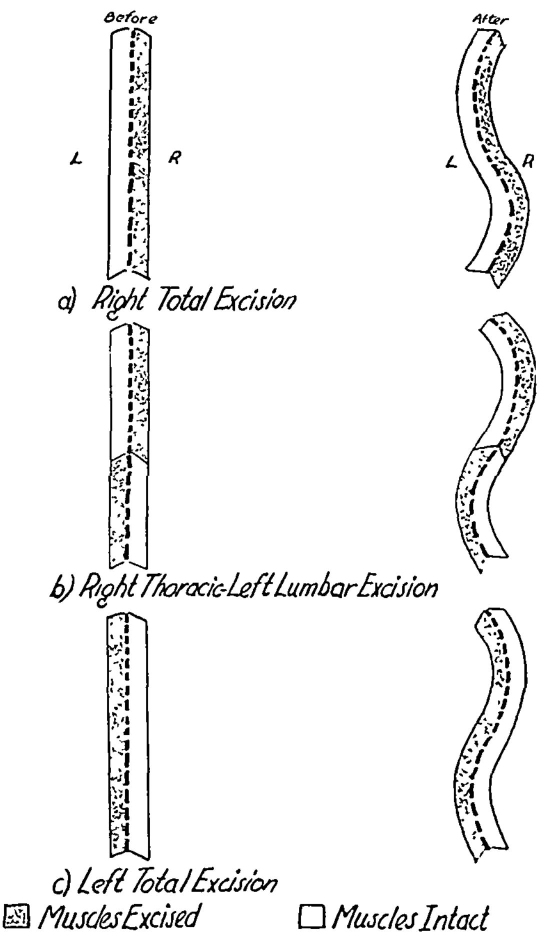

FIG. 2

Diagrammatic representation of the influence of the lumbar curve on the direction of the thoracic curve.

Experiment II (Mice)

1. *Unilateral Excision of Superficial and Deep Back Muscles (Ten Mice).* The procedure of unilateral excision of superficial and deep muscles as described in Experiment I was carried out on mice, except

TABLE I

RESULTS IN EXPERIMENT I

Procedure	Rat No.	Time Observed	Results
(1) Unilateral excision* of superficial and deep back muscles on the left.	1 2 3 4 5	12 months 12 months 8 months 12 months 12 months	Curve was convex to left in mid-thoracic region. Curve was convex to left in mid-thoracic region. Curve was convex to left in mid-thoracic region. Curve was convex to left in mid-thoracic region, and convex to right in lumbar region. No curvature was present, but spinous processes were rotated to right in thoracic region.
(1) Unilateral excision* of superficial and deep back muscles on the right.	6 7 8 9 10	3 weeks 12 months 12 months 12 months 12 months	Animal died 3 weeks postoperatively. No curvature was present. Curve was convex to right in mid-thoracic region. Curve was convex to right in upper thoracic region, and convex to left in lower thoracic and upper lumbar regions. Curve was convex to right in mid-thoracic region. Curve was convex to right in upper thoracic region, and convex to left in upper lumbar region.
(1) Unilateral excision* of superficial back muscles on the right.	21 22	1 month 12 months	Animal died 1 month postoperatively. No curvature was present. Mild curve was convex to left in thoracolumbar region.
(1) Unilateral excision* of superficial back muscles on the left.	23 24	12 months 12 months	No curvature was present. Mild curve was convex to left in thoracic and upper lumbar region.
(2) Bilateral excision* of superficial and deep back muscles.	11 12 13 14	8 months 12 months 8 months 12 months	No curvature was present. No curvature was present. No curvature was present. No curvature was present.
(3) Unilateral subperiosteal stripping on left, with insertion of rubber dam (4th through 13th thoracic). No excision of muscle.	16	4 months	Animal died 4 months postoperatively. No curvature was present.
(3) Unilateral subperiosteal stripping on left with insertion of insultoic membrane (4th through 13th thoracic). No excision of muscle.	18	12 months	Curve was convex to right in mid-thoracic region.
(3) Unilateral subperiosteal stripping on left, with insertion of cellophane sheet (4th through 13th thoracic). No excision of muscle.	20	4 months	Animal died 4 months postoperatively. No curvature was present.
(3) Unilateral excision* of deep and superficial muscles on left, and subperiosteal stripping with insertion of cellophane on right (4th through 13th thoracic).	15	3 months	Animal died 3 months postoperatively. No curvature was present.
(3) Unilateral excision* of superficial and deep muscles on left, and subperiosteal stripping with insertion of rubber dam on right (4th through 13th thoracic).	17	12 months	Curve was convex to left in mid-thoracic region.
(3) Unilateral excision* of superficial and deep back muscles on left, and subperiosteal stripping with insertion of insultoic membrane on the right (4th through 13th thoracic).	19	12 months	Curve was convex to left in mid-thoracic region.
Controls,—no operative procedure.	25 26	12 months 12 months	No curvature was present. No curvature was present.

* Extent of excision, 4th through 13th thoracic.

TABLE II

RESULTS IN EXPERIMENT II

Procedure	Mouse No.	Time Observed	Results
1) Total excision* of superficial and deep back muscles in the thoracic and lumbar regions, including the quadratus lumborum, on the right.	5	5 months	Curve was convex to right in upper thoracic region; convex to left in thoracolumbar region; and convex to right in low lumbar region. Pelvis was rotated to left.
	11	4 months	Curve was convex to left in thoracolumbar region, and convex to right in lumbar region. Pelvis was rotated to left.
	13	2 months	Curve was convex to left in thoracolumbar region, and convex to right in lumbar region. Pelvis was rotated to left.
	9	4 months	Curve was convex to left in thoracolumbar region, and convex to right in lumbar region. Pelvis was rotated to right.
	17	2 months	Slight curve was convex to left at thoracolumbar junction.
1) Total excision* of superficial and deep back muscles *in the thoracic and lumbar* regions, including the quadratus lumborum, on the left.	16	2.5 months	Curve was convex to left in lumbar region.
	8	6 months	Curve was convex to left in upper thoracic and *thoracolumbar regions (excision of lumbar* muscles had been incomplete). Pelvis was rotated to right.
	10	4.5 months	Curve was convex to left in upper thoracic region, and convex to right in thoracolumbar region. Pelvis was rotated to right.
	2	5 months	Curve was convex to left in upper thoracic region, convex to right in thoracolumbar region, and convex to left in low lumbar region. Pelvis was rotated to right.
	6	5 months	Curve was convex to right in thoracolumbar region, and convex to left in low lumbar region. Pelvis was rotated to right.
2) Excision of superficial and deep back muscles in the thoracic region on the right; and in the lumbar region, including the quadratus lumborum, on the left.	4	4 months	Curve was convex to right in thoracic region, and convex to left in lumbar region. Pelvis was rotated to right.
	14	1 month	Curve was convex to right in thoracic region, and convex to left in lumbar region. Pelvis was rotated to right.
Controls	1	4 months	No curvature was present.
	3	4.5 months	No curvature was present.
	7	4.5 months	No curvature was present.
	12	3 months	No curvature was present.
	15	2 months	No curvature was present.

* Extent of excision, 2nd thoracic through 6th lumbar.

that the muscles were excised from the second thoracic through the sixth lumbar, and the quadratus lumborum on the same side was also excised. In some cases, the peritoneal cavity was opened during removal of the quadratus lumborum, but the peritoneum was sutured with the lateral abdominal musculature to the psoas mass, in order to cover the defect produced in the peritoneum and thus prevent evisceration. No immediate postoperative deaths were encountered.

2. *Bilateral but Asymmetrical Excision of Superficial and Deep Muscles* (*Two Mice*). The superficial and deep muscles of one side of the thoracic spine were excised from the second thoracic through the thirteenth thoracic vertebrae, inclusive; and on the opposite side, the deep and superficial musculature was excised in the lumbar region from the first through the sixth lumbar vertebrae, inclusive, including the quadratus lumborum.

Five mice were used as controls.

DISCUSSION

The results of these experiments in a series of forty-three laboratory animals demon-

FIG. 3-A

FIG. 3-B

Rat 4. Showing curvature produced by unilateral excision of superficial and deep muscles of the back in the thoracic region, on the left.

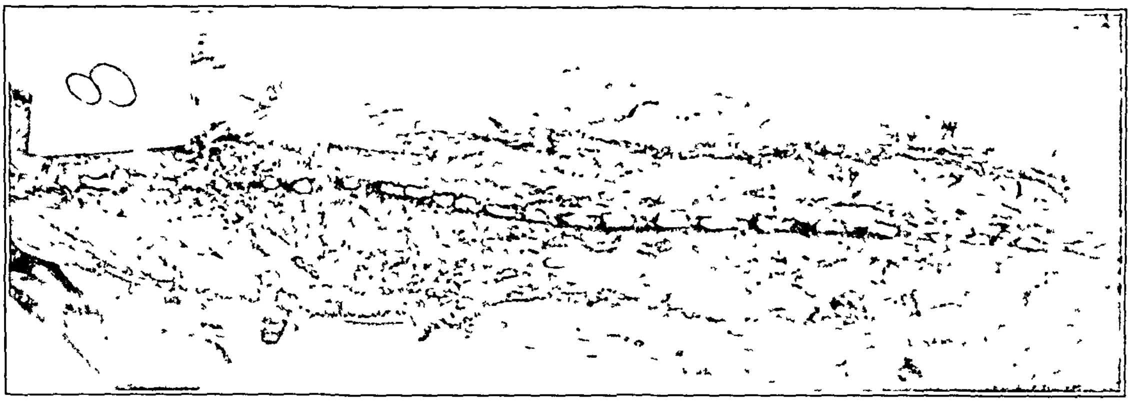

FIG. 4-A

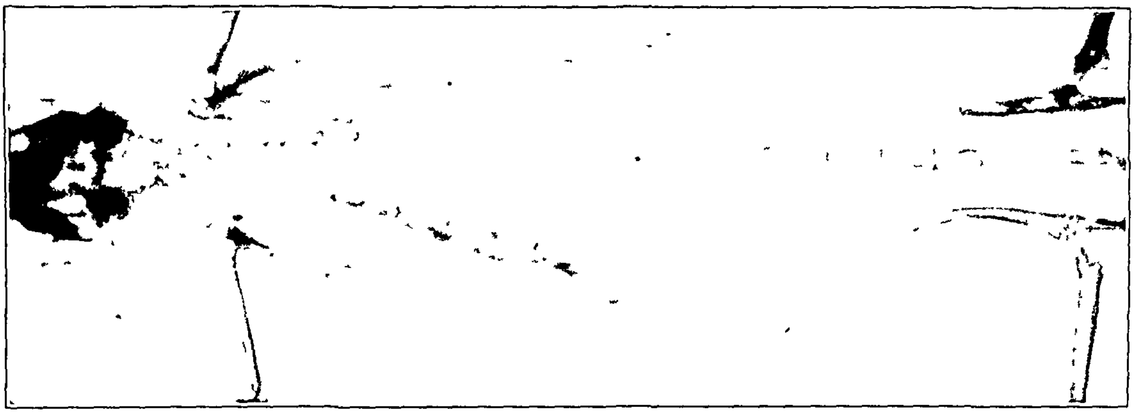

FIG. 4-B

Rat 8. Showing curvature produced by unilateral excision of superficial and deep muscles of the back in the thoracic region, on the right.

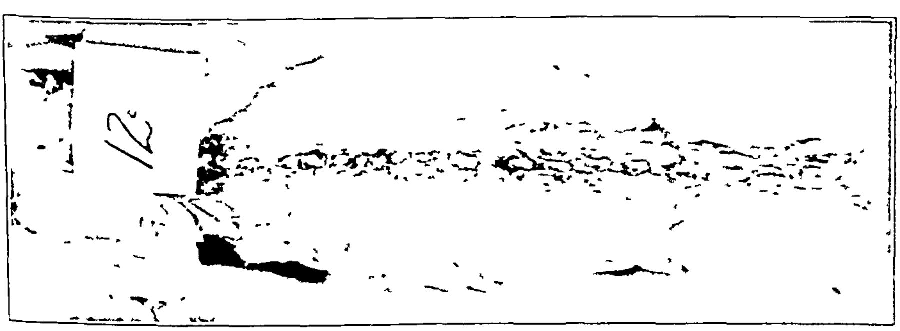

Fig. 5-A

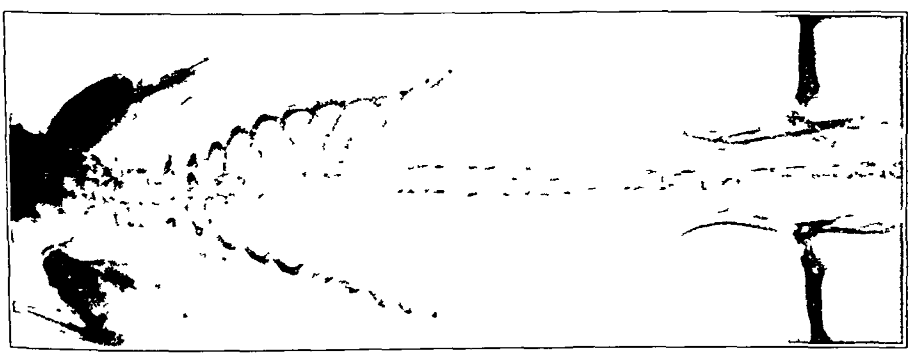

Fig. 5-B

Rat 12. Showing result of bilateral excision of superficial and deep muscles of the back in the thoracic region.

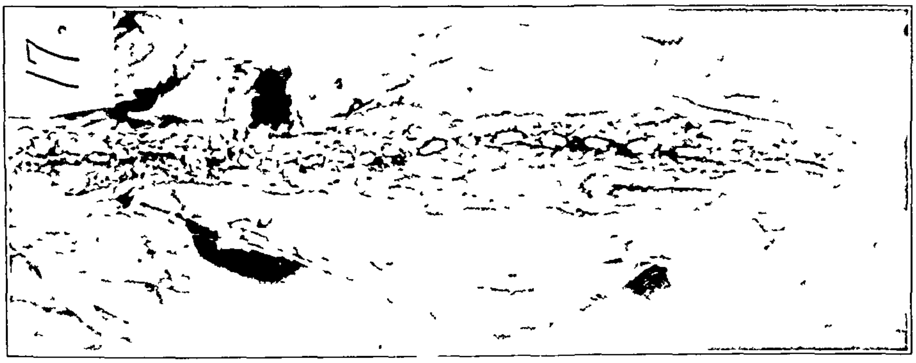

Fig. 6-A

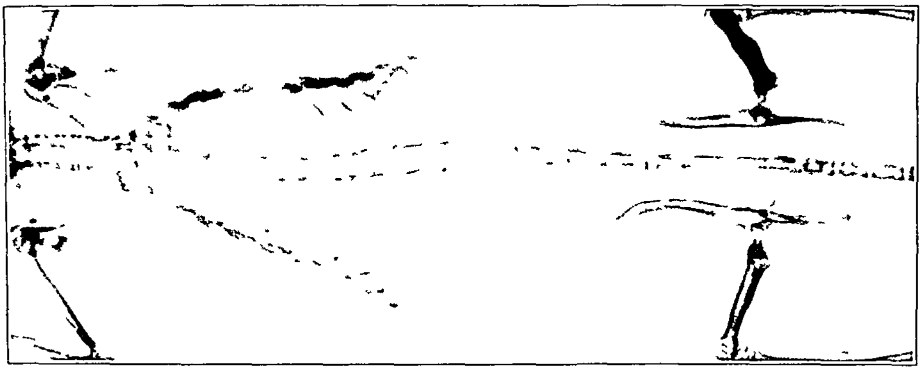

Fig. 6-B

Rat 17. Showing curvature produced by excision of superficial and deep muscles of the back in the thoracic region, on the left, and subperiosteal release of muscles of the back with the insertion of rubber dam on the right.

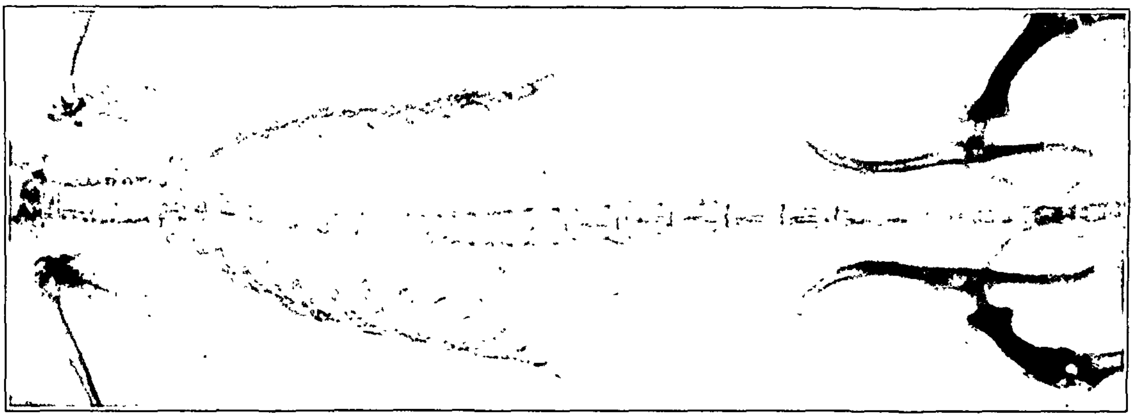

Fig. 8-B

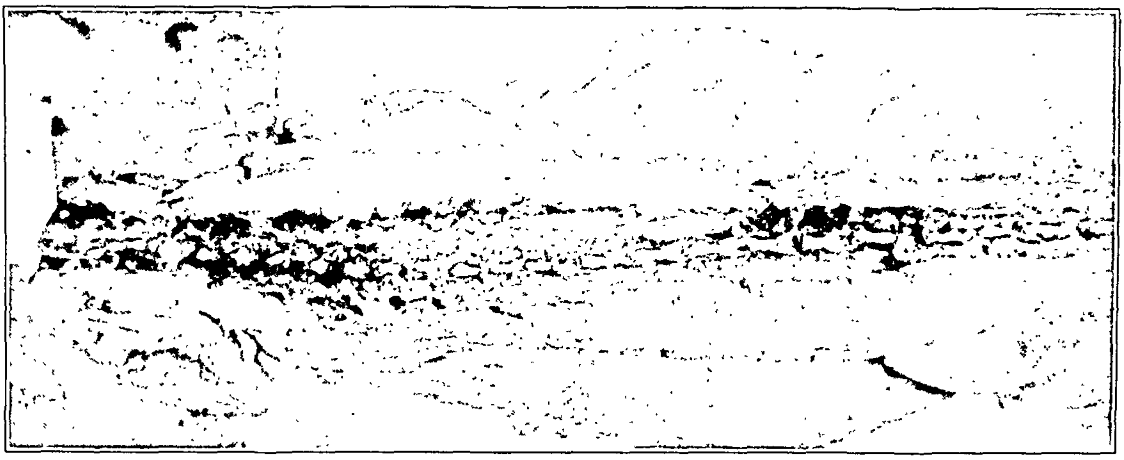

Fig. 8-A

Rat 24. Showing curvature produced by unilateral excision of superficial muscles of the back, on the left.

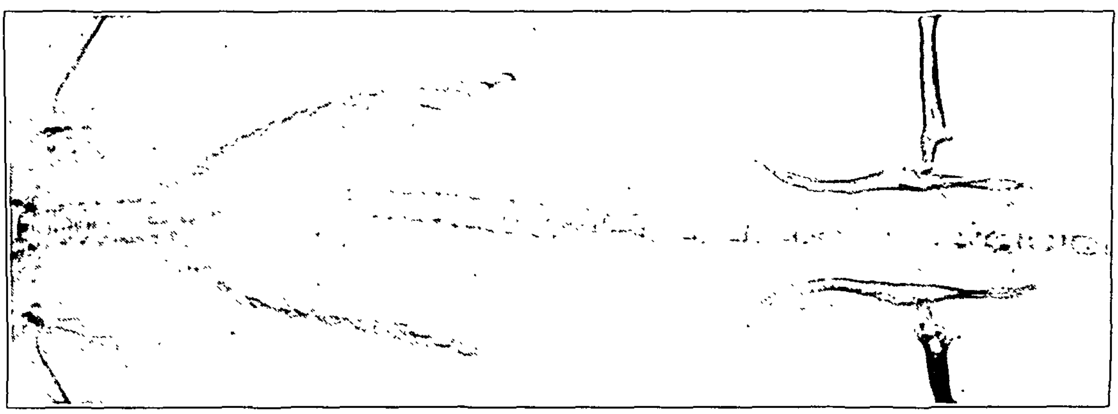

Fig. 7-B

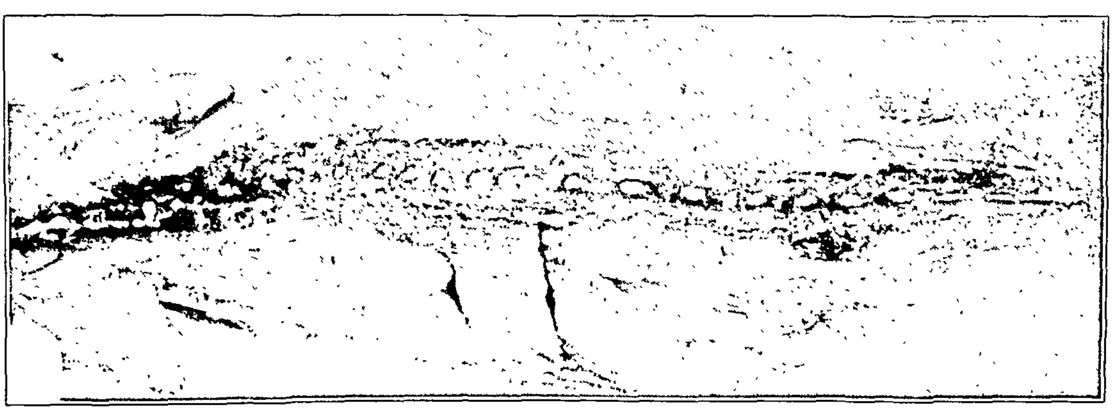

Fig. 7-A

Rat 18. Showing curvature produced by subperiosteal release of superficial and deep muscles of the back in the thoracic region, on the left, and the insertion of insultoic membrane.

FIG. 9-A FIG. 9-B

Mouse 5. Showing curvature produced by total excision of superficial and deep muscles of the back, on the right.

FIG. 10-A FIG. 10-B

Mouse 2 Showing curvature produced by total excision of superficial and deep muscles of the back, on the left

strates readily that scoliosis can be produced in quadrupedal animals, when muscle imbalance is obtained in those muscle groups affecting the alignment of the vertebral column. It is also apparent that a definite time element is necessary for the scoliosis to be produced. In rats, the minimum time for production of a lateral curve by the technique described is somewhere between four and eight months No curves were found in animals on whom autopsies were performed at or before four months, but expected curves were present in those on whom autopsies were performed at eight months. It was for this reason that the two experiments differed. In an effort to produce results earlier, the mice in Experiment II were worked on a treadmill, since it was felt that in a system of muscle imbalance, regular exercise would increase the power of stronger or unopposed muscles, and, thereby, would cause the scoliosis to appear sooner This contention is believed to be supported by the results, since curvature appeared as early as one month after operation in the mice. Definite evaluation of the influence of exercise on the time required for the production of curvature in such an experiment, however, calls for a series, comparable except for exercise, in the same type of animal.

In Experiment I, unilateral excision of deep and superficial muscles produced curvatures in a constant direction (Figs 3-A, 3-B, 4-A, and 4-B), the convexity being toward the weaker or "paralyzed" side, except for Animal 5, which showed no lateral deviation, but rotation of the spinous processes toward the stronger side.

Bilateral excision produced no muscle imbalance and thus produced no curvature (Figs. 5-A and 5-B).

The insertion of inert material to produce selective muscle imbalance offers a most interesting possibility for future investigation. Animals 17, 18, and 19 were the only three of this group which survived

FIG 11-A FIG. 11-B

Mouse 4 Showing curvature produced by excision of superficial and deep muscles of the back in the right thoracic region and the left lumbar region.

long enough for results to be observed. Both animals in which cellophane was used died within four months; whether or not the cellophane produced death is not known. One of the two animals in which rubber dam was used died at four months, the other (Animal 17) lived for the length of the experiment, and a curvature developed. In this animal (Figs. 6-A and 6-B), tissue section through the area of the rubber insertion (with Weigert stain) showed a marked amount of fibrosis. None appeared in Animals 18 and 19, in which insultoic membrane was used. Release of the attachment of the intrinsic back muscles on one side, with excision on the opposite side, resulted in curves convex to the weak side in Animals 17 and 19, whereas simple release of the attachment of the intrinsic muscle on the left in Animal 18 (Figs. 7-A and 7-B) resulted in a curvature to the right, which would be expected to be the stronger side. This indicates that the intrinsic or short back muscles may alter considerably the influence of the long or "bowstring" muscles on the alignment of the vertebral column.

The use of inert material to bring about selective muscle imbalance offers a means of studying the influence of certain individual muscle groups on the alignment of the vertebral column. In the animals studied, the use of insultoic membrane was found to be the most satisfactory, since microscopic sections through the areas of implantation of inert material showed that no local tissue reaction to the introduction of this substance was encountered, whereas considerable fibrosis and scarring were present around the insertions of cellophane and rubber dam.

No explanation is offered for the curvature being to the left only, in excision of either right or left superficial muscle groups (Figs. 8-A and 8-B).

In Experiment II, excision of the deep and superficial muscle mass throughout the length of the thoracic and lumbar spine produced double or S curves. Constantly the convexity was toward the weak side in the lumbar region, as one would expect. The thoracic curve, however, was convex toward the stronger side. When the direction of the lumbar curve favored it, as in Animal 4, the thoracic curve was convex toward the weak side, as in excision of the right thoracic and left lumbar musculature (Figs. 9-A, 9-B, 10-A, 10-B, 11-A, and 11-B). Comparing this with the results in Experiment I, where it was found that with thoracic-muscle imbalance only, the convexity was toward the weak side, *it is strongly suggested that a lumbar curve will ultimately affect the direction of the thoracic curve.* This statement is presented diagrammatically in Figure 2. An inconsistency in this observation is apparent in Animals 8 and 10, but we believe that incomplete excision of the lumbar-muscle group in Animal 8 may account for the deviation from the expected results. In Animal 10, the period of observation was only four months, the low convexity to the right was in the thoracolumbar region, and it may be suggested that the curve was not fully developed at the time the animal died.

Experiment II also demonstrates a method of studying the progressive stages between beginning and maximum curvature. For example, animals observed for periods of two, four, and five months, following right total excision, showed varying degrees of curvature from mild single-curve scoliosis to severe triple curvatures, with a left convexity in the thoracolumbar region common to all the animals. Animals observed for periods of from two and a half to six months following total excision on the left also showed curvatures varying from single-curve scoliosis to triple curvatures.

Carey, by the medium of an ingenious mechanical system, demonstrated the influence of individual muscle pull on the alignment of the vertebral column. He also demonstrated mechanically that combinations of muscle groups in balance and in imbalance have definite and constant influence on the vertebral alignment.

In this experiment there have been demonstrated, *in vivo*, some of the mechanical imbalances presented by Carey in an inanimate model. Thus scoliosis has been produced by selective muscle imbalance, which simulates the mechanical condition of paralytic scoliosis.

Scoliosis, secondary to poliomyelitis, is dependent upon muscle imbalance, which is

due to asymmetrical paralysis of muscle groups, influencing the normal alignment of the vertebral column. This imbalance may be mild or severe in degree; the location and nature of the curve is dependent upon the type and extent of the imbalance.

Crego and McCarroll have demonstrated that recurrence of deformities in paralytic feet after stabilization may frequently be due to uncorrected muscle imbalance about the foot and ankle; the same principle may well hold true in deformities of the vertebral column, which are due to or influenced by muscle imbalance.

It is believed that the results obtained in this series of animals have been constant enough to warrant certain definite conclusions.

CONCLUSIONS AND SUMMARY

This study of experimentally produced scoliosis may justify the following conclusions:

1. Scoliosis can be produced experimentally in laboratory rats and mice by the selective release of mechanical action of different muscle groups on the vertebral column.
2. A satisfactory degree of control can be maintained to allow the prediction of the type of curve to be produced.
3. Selective muscle imbalance can be produced without muscle excision by the use of inert material to prevent muscle reattachment; this imbalance will produce lateral curvature.
4. Muscle excision and release which did not produce imbalance resulted in no scoliosis in the animals studied.

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Photographic and roentgenographic material was obtained through the cooperation of Miss A. J. Joslin, R.N., Shriners' Hospital, and Mr. M. W. Rhoades, Washington University.

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CONGENITAL STRICTURE OF THE SPINAL CANAL*

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It is a common phase of pathology that peripheral nerves are very susceptible to pressure, whether this be the sudden pressure of a fractured bone fragment, the gradual pressure of exuberant callus, or the slow envelopment of scar tissue. The nerve gives evidence of the pressure by sensory and motor changes in the part supplied, varying from muscle weakness to complete paralysis, from mild hypaesthesia to complete anaesthesia. Despite this well-known fact, we have thus far largely neglected the study of the congenital causes of pressure against one of the most important parts of the nervous system,—the spinal cord. I refer particularly to the congenital stricture of the spinal canal.

Normally, the spinal canal is narrow in three regions,—above, below, and between the cervical and lumbar enlargements. The spinal cord shows similar variations in its size. Although it is impossible to prove that the enlargement of the canal has any effect on the enlargement of the cord, we do know that in spina bifida occulta there is a stricture of the cord. This causes many clinical manifestations: enuresis of varying grades, pains similar to those in lumbago and sciatica, atrophy of muscles, skin changes similar to vitiligo, and perforating ulcer. I have published papers which show additional effects of

FIG. 1

Case 1. Sevim. The autopsy specimen shows that the spinal cord is divided into two lateral branches, and is reunited after the division. (*Reproduced from Vertebra Bifida.*[2])

FIG. 2

Case 2. Metin. At autopsy, the spinal cord was found to be like that in Case 1,—divided into two branches by a bone and reunited after the division.

* Edited by Leo Mayer, M.D., New York, N. Y.

spina bifida occulta and the associated congenital stricture,—retention of urine caused by paralysis of the urinary bladder, pollakiuria, malacic disease of the legs, retraction of the urinary bladder caused by a cystitis resisting treatment, and ascending inflammation of the urinary tract caused by enuresis. In fact, 56 per cent. of the cases of urinary calculi in Turkey, which were caused by a long continued cystitis, were due to stricture of the spinal canal.

Thus far, there have been no references in the medical literature to congenital stricture not associated with spina bifida occulta. Studies extending over a long period have convinced me, however, that this pathological entity does exist, that it can be demonstrated by suboccipital injections of lipiodol, and that it is responsible for many hitherto unexplained clinical manifestations,—enuresis, spastic or flaccid paralysis, and various deformities. These patients do not suffer pain. It might, therefore, be argued that no pressure is exerted against the cord. My answer is that certain spinal tumors, which grow slowly, may exist for years without causing pain. Thus Sicard and Laplane, in *La Presse Médicale* of January 10, 1925, reported the case of a soldier in whom, in 1916 following a concussion of the brain, a spastic paralysis developed. This was variously diagnosed as hematomyelia, syringomyelia, multiple sclerosis, Pott's disease, and myelitis syphilitica. The patient had no pain. Despite this, Sicard suspected a spinal-cord tumor, because of a lipiodol block following suboccipital injections, and cured him by laminectomy and removal of the tumor.

Just as tumors of the spine may cause spastic or flaccid paralysis, so congenital strictures may produce one or the other form of paralysis. The particular type is due not to the location of the lesion, but to the degree of pressure exerted on the cord.

Thus far, I have been able to differentiate the following forms of congenital stricture of the spinal canal:

1. A narrowing of the canal, forming a ringlike constriction of the cord at one or more levels. This variety is usually found in cases of enuresis, and is readily cured by laminectomy. The relief of symptoms comes within a few hours of the operation.

2. More extensive strictures, involving an entire region of the canal. This type is usually associated with spastic paralysis similar to that seen in Little's disease.

3. A localized stricture, causing compression of the spine and paralysis of certain groups of muscles. This is the type responsible for club-foot.

4. Atypical cases, causing a cleft either in the cord alone or in both cord and dura mater.

Our knowledge of the last group is based on two postmortem examinations.

FIG. 3-A

Case 3. Naci. Roentgenogram of patient with enuresis, showing spina bifida occulta at the fifth lumbar vertebra.

FIG. 3-B

After a suboccipital injection, the lipiodol stayed at the first lumbar vertebra where there was no spina bifida occulta.

CASE 1. Sevim, a child, five months old, was admitted to our Clinic, December 2, 1936. There was a tumor in the

FIG. 4-A

Case 4. Fehmi. Roentgenogram of a patient with enuresis showed spina bifida occulta of the first sacral vertebra.

FIG 4-B

After suboccipital lipiodol injection, the lipiodol remained at the third lumbar vertebra, where there was no spina bifida occulta.

FIG. 4-C

After laminectomy, part of the lipiodol descended to the sacral vertebra.

FIG. 5-A

Case 5. Serafettin. Roentgenogram of a patient with enuresis showed spina bifida occulta.

FIG. 5-B

After suboccipital lipiodol injection, the lipiodol remained at the third lumbar vertebra.

FIG. 6

Case 6. Meliha. This patient had enuresis, but no spina bifida occulta; however, the lipiodol stops at the third lumbar vertebra.

lumbar region as large as an orange, covered with a thin layer of normal skin. Pressure against the tumor caused a bulging at the fontanel. The right leg showed slight paresis, the left foot was claw-shaped, and the big toe was held hyperextended. The right leg was hypaesthetic, the left had normal sensitivity. The roentgenogram of the spine showed failure of fusion of the arches of many vertebrae posteriorly. Twenty-four hours after the resection of the tumor, the child died of shock. At autopsy, an extensive bone formation was found, which divided the spinal cord into two lateral parts (Fig. 1). This bone flattened the posterior portion of the canal to such an extent that the spinal cord bulged out through the hiatus in the posterior arches of the vertebrae.

CASE 2. Metin, five years old, born in Instanbul, was admitted because of abnormal gait. There was a tumor the size of a nut in his lumbar region. At operation, extensive bone formation within the canal was found, similar to that in Case 1. This divided the cord into two lateral halves. The dura mater was attached to the bone. The bone was removed in part by rongeurs, but the child died of shock within twenty-four hours. At autopsy, a marked constriction of the canal was found. The compression of the cord was due in part to the abnormal bone formation, and in part to a sleeve of fibrous tissue (Fig. 2).

In the group of cases associated with enuresis, we have noted the lipiodol block usually at the level of the second or third lumbar vertebra (Figs. 3-B, 4-B, 4-C, 5-B, and 6). We know that this represents the region of the spinal cord which controls the bladder. These patients represented a group with severe symptoms not controlled by any conservative measures. At operation it was noted that, before release of the constriction, there was no pulsation of the dura below the level of the lesion; that pulsation returned after laminectomy; and that, as the pressure was released, the dura, together with the epidural fat, bulged through the opening in the region of the laminectomy. These facts, together with the immediate cure of the enuresis following the operation, have convinced us of the presence of a stricture which exerts a significant pressure against

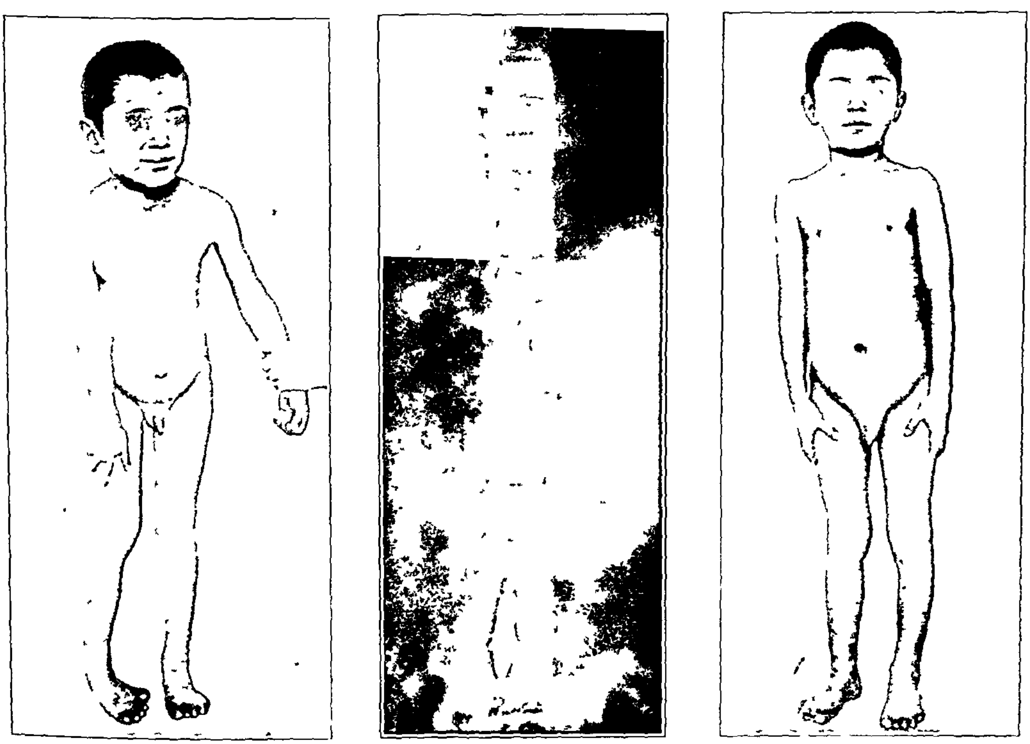

FIG. 7-A FIG 7-B FIG 7-C

Fig 7-A: Case 7. Rustem. Showing patient before laminectomy

Fig. 7-B: After suboccipital injection, the lipiodol remained at the first sacral vertebra, where there was no spina bifida occulta.

Fig. 7-C: Showing patient after laminectomy

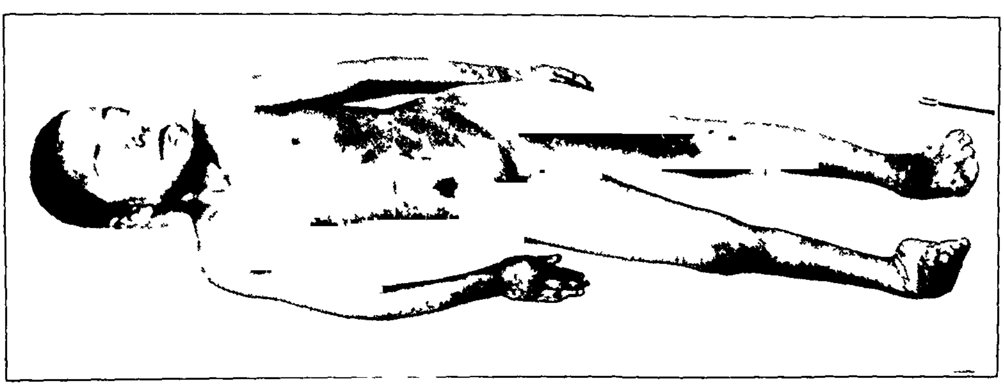

FIG. 8-A

Case 8. Mustafa D. Photograph before laminectomy.

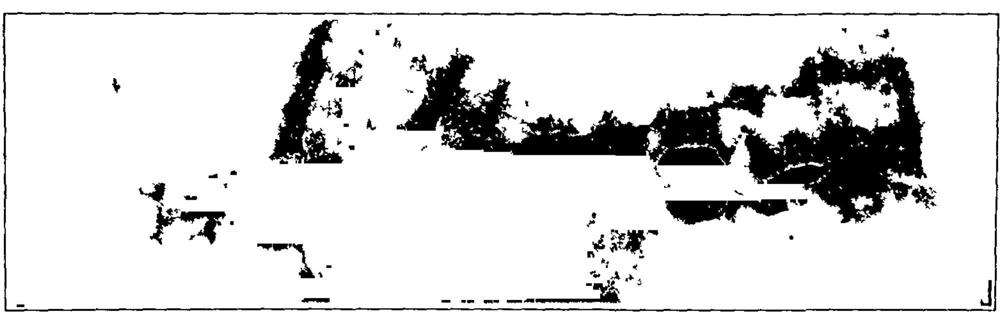

FIG. 8-B

Two and a half hours after lipiodol injection.

FIG. 8-C

Twenty-four hours after suboccipital lipiodol injection.

FIG. 8-D

Showing condition after laminectomy.

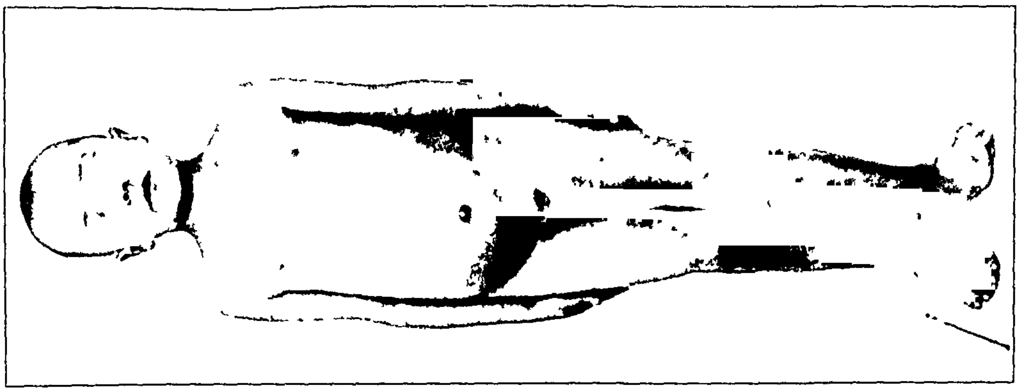

FIG. 8-E

The hygroma was not operated upon, as it was thought that this would disappear in time.

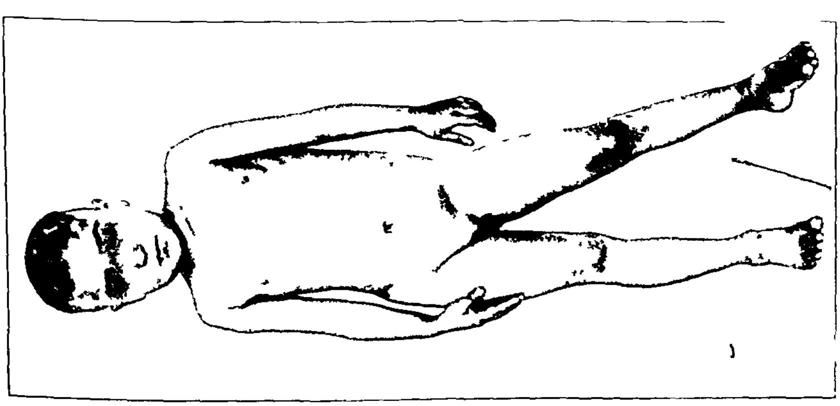

FIG 9-A Case 9 Nermin Photograph taken before laminectomy, showing pes equinovarus

FIG 9-B Twenty-four hours after suboccipital lipiodol injection, the lipiodol remained at the first lumbar vertebra where there was no spina bifida occulta.

FIG 9-C After laminectomy, the lipiodol descended to its normal place.

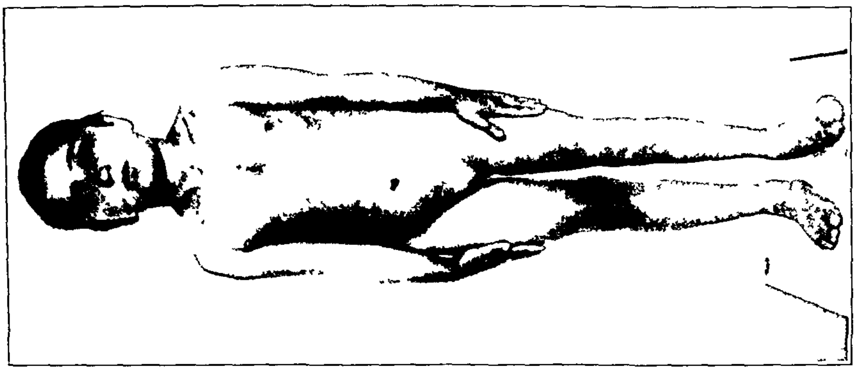

FIG. 9-D Showing improved condition after laminectomy.

the cord. Although we thought at first that the strictures were always associated with spina bifida occulta, recent cases have demonstrated their presence without demonstrable evidence of spina bifida (Fig. 6).

Our research has demonstrated that many club feet, some of them of the paralytic type, are due to congenital stricture of the canal. Laminectomy has cured these patients. The following illustrative cases are typical.

CASE 7. Rustem, seven years old, had a right club foot, and had never been able to walk normally. The deformity was said to have existed since birth. There was no history of poliomyelitis. Examination showed a paralytic club foot, due to paralysis of the peroneal muscles and the extensor digitorum longus. This paralysis was confirmed by exact electrical tests. In order to walk, the patient had to abduct the right thigh and support it with his hand (Fig. 7-A). After walking a few steps, he tended to fall. The reflexes were normal. Wassermann reaction was negative. A suboccipital injection of lipiodol showed a narrowing of the lipiodol column at the level of the fifth lumbar vertebra (Fig. 7-B). Following laminectomy in this region, he was able to stand and walk normally, and the club-foot was corrected (Fig. 7-C).

CASE 8. Mustafa, ten years old, had a club foot even more severe, which was complicated by a large hygroma on the dorsolateral aspect of the foot. The deformity was so severe (Fig. 8-A) that manual correction was impossible, and a bone resection was thought to be necessary. The peroneal muscles were paralyzed. The lower half of the leg and the foot were cold and cyanotic. The left foot showed a plano-valgus deformity. There was no history of poliomyelitis. Before any local operation was attempted, a suboccipital injection of lipiodol was given. This showed a peculiar spinal twist of the lipiodol column and a stricture at the level of the fourth lumbar vertebra (Figs. 8-B and 8-C). After laminectomy it was possible to correct the club-foot by simple lengthening of the Achilles tendon by the method of von Baeyer (Fig. 8-E). The hygroma was not removed, because it was thought it would probably disappear spontaneously.

CASE 9. Nermin. In this case, the club-foot was somewhat milder (Fig. 9-A). The lipiodol showed a block at the first lumbar level (Fig. 9-B). The photographs illustrate the result of laminectomy (Figs. 9-C and 9-D).

CASE 10. Zeyneb. This was a most unusual case in an adolescent girl, who, on admission to our Clinic, was barely able to stand alone. Both hips and knees showed marked flexion contractures; both hips were dislocated; the feet were cold; and many of the nails were absent (Figs. 10-A, 10-B, and 10-C). The cause of her contractures was inexplicable until the lipiodol injection showed a stricture at the level of the second, third, and fourth lumbar vertebrae (Figs. 10-D and 10-E). During the laminectomy of the second, third, and fourth lumbar vertebrae, it was noted that the spinal canal was so narrow that it was impossible to introduce a little finger, and there was no pulsation of the dura mater. It seemed to us that there was such a marked failure of development of the cord that the operation would probably prove a failure, and for this reason we did not extend the laminectomy to

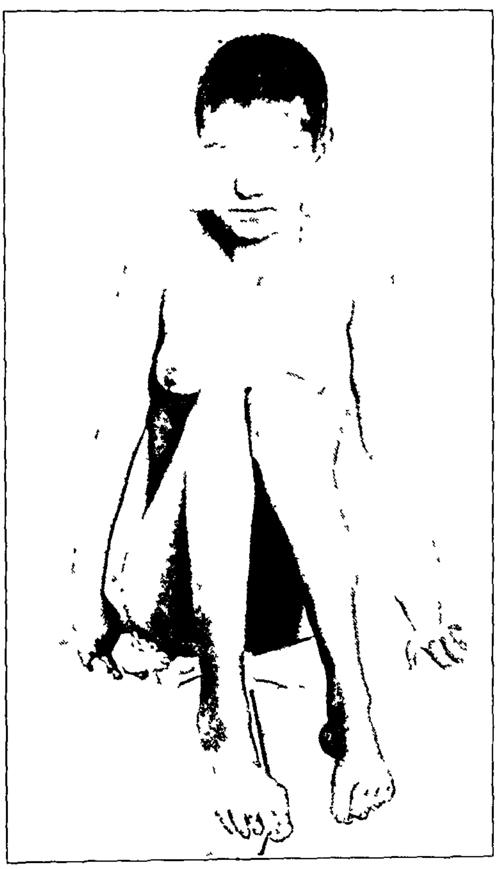

FIG. 10-A

Case 10. Zeyneb. Girl in seated position. Note appearance of feet and toes.

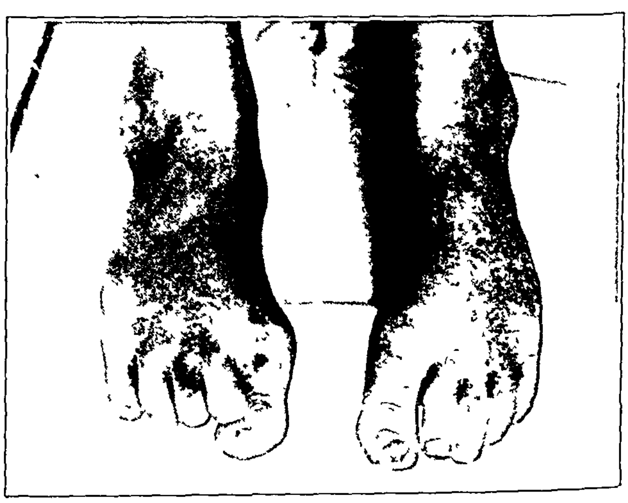

FIG. 10-B

Photograph showing feet and toes.

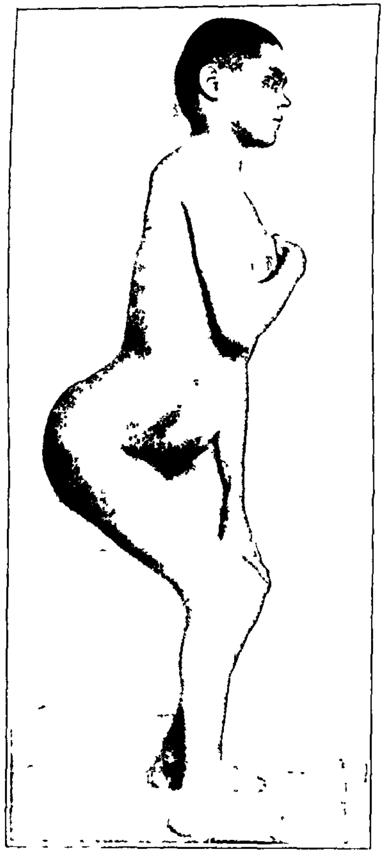

FIG. 10-C

Before laminectomy, the patient was able to stand up only by leaning on the wall.

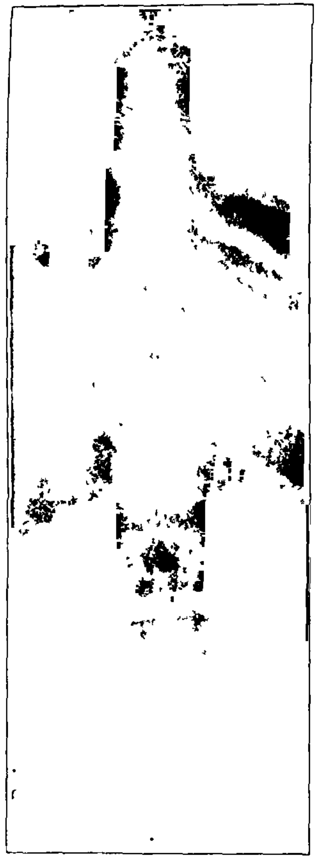

FIG. 10-D

Roentgenogram shows no *spina bifida occulta*.

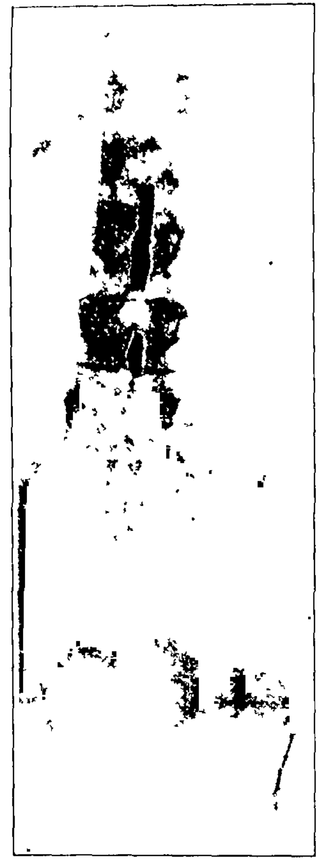

FIG. 10-E

Twenty-four hours after suboccipital lipiodol injection, the lipiodol remained at the second, third, and fourth lumbar vertebrae.

FIG. 10-F

Four months after laminectomy, the patient can stand up and walk slowly without leaning on anything.

FIG. 11-A

Case 11. Dudu. This patient had paraplegia spasmodica (Little's disease). The roentgenogram shows no spina bifida occulta.

FIG. 11-B

Twenty-four hours after suboccipital lipiodol injection, the lipiodol remained at the second lumbar vertebra. The patient could not walk at all. Three months after laminectomy, she was able to walk without leaning on anything.

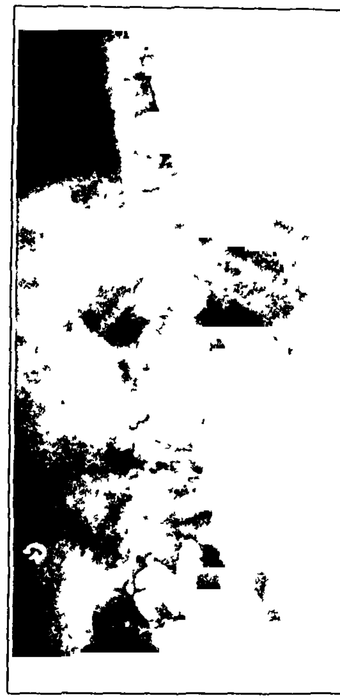

FIG. 12

Case 12. Mustafa. The patient suffered with enuresis and had a spina bifida with tumor in the sacral region. After laminectomy, the enuresis was not improved. Suboccipital lipiodol injection was made in our Clinic a year later.

FIG. 13

Case 13. Cemal. This was a case of continual enuresis. The patient had a sacrum bifidum and spina bifida with tumor at the first lumbar vertebra The tumor was extirpated, but the enuresis did not improve.

the thoracic region. To our surprise, however, one month after the operation, the patient had improved enough to walk 120 yards, leaning on a wall, and after four months she could walk without any support (Fig. 10-F).

In ten patients with spastic diplegia, similar to that seen in Little's disease, we found that the lipiodol was blocked, and at laminectomy we were able to prove the narrowing of the spinal canal (Fig. 11-B).

From the study of this series, we are reasonably sure that congenital stricture or narrowing of the canal is responsible for many cases of enuresis, club-foot, and spastic and flaccid paralysis leading to abnormalities of gait and contractures. The narrowing of the bony canal compresses the cord, and, by the law of Delpech, prevents it from normal development. It is also probable that there are congenital strictures of the intervertebral foramina, which cause pressure against the nerve roots. These lesions, unlike those in later life, do not cause pain, since they develop very slowly and tend to inhibit growth of the nerve, whereas the inflammatory constrictions of later life cause sudden pressure against a fully developed nerve, and are, therefore, painful.

The indications for laminectomy are as follows:

1. In uncomplicated cases of enuresis, laminectomy may be postponed until puberty.

2. All patients with enuresis, who have reached adolescence without improvement, require laminectomy.

3. In children of four or five years, who, without assignable cause other than con-

genital stricture of the spinal canal, have never learned to walk, laminectomy should be done without delay, since otherwise irreparable damage to the cord may occur.

4. In cases of abnormal gait, which tend to become worse, and which show congenital stricture of the canal, operation should be done when the patient is five or six years of age.

5. The same rule applies to patients with atrophy or paralysis combined with abnormalities of the lower extremities.

As to the technique of the operation, the laminectomy should include the narrow vertebra and the one just distal to it. In cases of spastic diplegia, five or six vertebrae should be included. The stricture must be completely relieved, and pulsation must return to the dura below the level of the lesion. Great care should be taken not to injure the dura; sponging should be done very gently. If by accident the dura is opened, it should be sutured in such a way as not to cause any constriction. In cases of spina bifida, it is important not only to remove the tumor, so as to prevent its rupture and subsequent infection, but also to release the concomitant stricture, since otherwise symptoms due to agenesis of nerves will probably continue (Figs. 12 and 13).

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SOME REMARKS ON THREE COMMON FRACTURES *

1. FRACTURES OF THE CARPAL SCAPHOID;
2. FRACTURES OF THE HEAD OF THE RADIUS;
3. FRACTURES OF THE MEDIAL MALLEOLUS.

BY D. M. MEEKISON, M.D., B.SC., F.A.C.S., VANCOUVER, BRITISH COLUMBIA, CANADA

Fractures of the carpal scaphoid, head of the radius, and medial malleolus were encountered very frequently in the Royal Air Force during the author's years of service in that branch of the British Armed Forces. Certain conclusions on some aspects of these will be presented, perhaps dogmatically, together with series of cases of each fracture, composed of the author's patients, accumulated for the most part during one year.

FRACTURE OF THE CARPAL SCAPHOID

In considering this fracture, one is reminded of an apt remark by André Gide, who prefaced an essay with:

"*Tout c'est déjà dite; mais comme personne n'écoute, c'est toujours nécessaire à recommencer!*" †

How true this is of scaphoid fractures! How much preaching and writing and investigating have been done on this subject; yet we cannot persuade everyone to immobilize this bone as soon as it is fractured. Indeed, we cannot make the members of the medical profession sufficiently scaphoid-conscious to have a roentgenogram taken and to make a diagnosis.

Pathology

To create and maintain conditions optimum for blood supply is the surgeon's chief concern. Immobilization of fresh fractures in hyperextension and full radial deviation so impacts the fragments that nourishment is forever cut off from the underfed proximal fragment. Those who decry open operation through a dorsal approach, because the exposure interferes with the blood supply, will purposely and with intent drill a hole through the tubercle and insert a bone graft for established non-union. Surely the nutrient artery enters the bone at that point.

It is difficult to understand why a fracture occurs in the proximal third, since the bone is so well protected from strain at this level. On the other hand, fractures of the waist are quite logical, since the scaphoid lies virtually half in the proximal row and half in the distal row of the carpus; and thus is the only member of this carpal family subject to certain shearing and rotational strains. This brings up the interesting question of why so many fractures of the carpal scaphoid are encountered in the Services, in contrast to the paucity of Colles's fractures. It would seem that the scaphoid fracture is one of youth, due possibly to the fact that strong forearm muscles resist hyperextension and thus project the leverage more distally.

Diagnosis

The expression "sprained wrist" is all too common. Roentgenograms of such a wrist in at least four projections are essential. If one suspects clinically a fracture of the scaphoid, even though the roentgenograms do not reveal it, the wrist should be immo-

* Read at the Annual Meeting of The American Orthopaedic Association, Hot Springs, Virginia, June 1, 1944.

† "All has already been said; but, as no one has listened, it is always necessary to start over again!"

bilized for about three weeks and the roentgenographic study should be repeated. In eight of this series, no fracture was revealed in the original roentgenogram, but was evident three weeks later. This is a most important point.

Another feature of the roentgenographic interpretation is the possibility of overlooking a subluxation of the semilunar; its relationship to the other carpal bones should, if abnormal, be adjusted.

Treatment

Fractures of the carpal scaphoid should be considered under two headings. The first group, fresh fractures, are not a problem; the second, old fractures, are a problem.

Orthopaedic or traumatic surgeons should not miss a fracture of the scaphoid, and, if given the opportunity, they should obtain good results in fresh fractures by closed methods in 100 per cent. of the cases. By closed methods is meant adequate immobilization in plaster in the position best described by Soto-Hall and Haldeman, for eight weeks or more. Properly applied, the plaster need not be changed in less than eight weeks, and by then union is likely to be present. This refers, of course, to waist fractures and those proximal to this level. Tubercle fractures need hardly be treated at all. In cases treated during the past eighteen months, the author has included the thumb in the cast, with the first metacarpal abducted, and has continued the cast to the proximal interphalangeal joints, as suggested by Soto-Hall and Haldeman. It has been gratifying to see the way the plasters stand up. The scaphoid can be immobilized by a shorter cast, but the cast does become loose and requires changing every three or four weeks.

In the treatment of old fractures (unrecognized or untreated for a month or more) there are four methods to consider.

1. *Immobilization.* An old fracture must be immobilized for from four to six months if necessary, depending upon roentgenographic evidence of union; and union must be complete. This treatment is reserved for fractures which are not too old—that is, one to three months—and in which accurate reduction can be obtained.

2. *Excision.* This applies to the proximal fragment, when it is the smaller of the two and shows evidence of aseptic necrosis. Excision should never be done when the fracture is at the waist. If excision is undertaken, it should be done early, before changes can take place in the articular cartilage of the radius. Aseptic necrosis can be recognized by the end of eight weeks.

3. *Bone Graft.* The simple dorsal approach, using a peg or inlay graft, is the safest. In seventeen of the 115 cases, bone grafts of this type were used and produced good results. This procedure was originally described by Gordon Murray, and, with modification, it offers the opportunity of holding the fracture reduced by means of a Thomas spike *, while the graft is placed. The use of the blind peg graft is unwise. It is time-consuming and not always accurate. It is difficult to place a straight graft in a curved bone, and the author has seen the radius, the semilunar, and even the ulna, impaled by this procedure. Furthermore, anatomically, it must destroy the nutrient artery.

4. *Arthrodesis of the Wrist.* In old scaphoid fractures with arthritic changes in the adjacent carpal articulations, any surgical procedure short of arthrodesis of the wrist is futile. Arthrodesis offers freedom from pain and a strong wrist, if adequately done. It is true, dorsiflexion and volar flexion are lost, but supination and pronation, which are far more important, are preserved. The procedure of choice is the bail graft, described by Brittain. It really works beautifully, but Brittain has neglected to mention, in the description of his operation, the necessity of eliminating all available articular cartilage.

* This instrument will be found most useful in many open operations on bones and joints. It would seem to have been devised by a surgeon of St. Thomas's Hospital in London in the years gone by, and named by him after his Hospital. It is something like a raspatory, about eight inches in length, with a slightly curved and rounded blunt tip and a fenestrated handle. One may poke about with it in all manner of places without doing damage.

Analysis of Series

Of the 115 cases in this series, seventy-seven were treated from the beginning, and could be considered fresh fractures. It is interesting to note that of these, sixty gave excellent results by adequate immobilization; the remainder of the group were still under treatment when the author left the station. When first seen, thirty-eight had been without treatment for a month or longer (in some cases, even years after the original injury). In this group the following complications were found: arthritic changes in fourteen, cystic degeneration in twenty-two, and aseptic necrosis of the proximal fragment in two. Of the 115 cases, only four resulted from aircraft crashes. Ninety-three were fractures at the waist, fifteen were distal to the waist including the tubercle, and seven were in the proximal third of the bone.

FRACTURES OF THE HEAD OF THE RADIUS

Pathology

The radiohumeral articulation is a precision joint; the slightest eccentricity, caused by tilting of the head, limits its function. Nor is there any room between the head of the radius and the capitellum for any extraneous material,—such as that produced by a fracture through the head. It would seem logical, then, that a damaged or tilted head is a detriment to the function of the joint, and should be removed. This was our very definite conclusion in this series, with the reservation that, if the fracture is not fresh, a good result—such as one obtains in excision of the head following a fresh fracture—is not to be anticipated.

The patients who were not operated upon came early in the series, and were considered to be borderline cases at that time. Their convalescence was so tedious that we wished, in the light of our later knowledge, that we had done an early excision of the head. The incidence of visible damage of the capitellum, as seen at operation and not visible roentgenographically, was striking. On reflection, it is a logical result of the injury. Either the head of the radius strikes the capitellum or the capitellum strikes the head of the radius. If there is sufficient force to damage the head of the radius, so that the damage can be seen in the roentgenogram, then there must be some damage to the capitellum. When both are damaged, dysfunction must result.

Why fractures of the head of the radius are so extraordinarily common in the Service is not clear. Two factors, at least, contributed in no small way to our series,—falls from bicycles and falls during the blackout. Falls in the blackout were extremely common, and not infrequently resulted in fractures of the scaphoid or of the head of the radius. Bicycles were in exceedingly common use. Oddly enough, the bicyclist not infrequently falls with the elbow underneath him, and not on the outstretched hand; it is in these accidents, almost invariably, that the most severe damage is done to the articular surface of the capitellum.

Treatment

The fresh fracture in patients beyond the growth period is really not a problem. Excision within a week or so of injury is advocated; and the excellent results obtained justify the treatment. The old fracture, with organized transudate within the capsule, with limited movement, and with pain at the extremes of the arc of movement, is a real problem. One may easily correct the mechanical disadvantage of an irregular or eccentric head, but, so far as I am aware, there is no solution for the problem presented by changes that have taken place in the capsule.

Operation. With the elbow flexed to about 90 degrees and the forearm pronated, the shortest possible incision, 3 to 3.5 centimeters, is made, axial in direction and lateral to the head of the radius. It is so placed that the joint level is approximately at the junction of

common. This is one of the most important items in Dr. Meekison's paper. His statements are confirmed by the experience of the Canadian Army. I know from my experience and from conversation with Lieutenant Colonel Shands that fracture of the carpal scaphoid in men undergoing training is a common experience.

The next item of importance is that the fracture is easy to overlook. Often the injury is diagnosed as a sprained wrist and it is not until considerably later that the fracture is demonstrated by roentgenogram. I have come to believe that the lesion of sprained wrist is very uncommon. Far more frequently what is called "sprained wrist" is a fracture of the carpal scaphoid. It is a sound rule that patients who seem to have a sprained wrist should have a roentgenographic examination to determine whether or not they have a fracture of the carpal scaphoid.

When we state that fractures of the carpal scaphoid are of common occurrence and that they can be recognized on the roentgenogram, it should be clearly stated also that sometimes the initial roentgenogram fails to reveal the fracture. If symptoms persist, following an injury to the wrist in which the initial roentgenogram was negative, another roentgenogram should be taken in ten days to three weeks. Often, the later roentgenogram will reveal the line of fracture which failed to show in the earlier roentgenogram.

The treatment which Dr. Meekison has outlined (early and adequate fixation carried out for a reasonable length of time) is simple and satisfactory; this will result in union in virtually every case, unless there has been considerable displacement of the fragments.

Recently Colonel MacFarlane, who, you will remember, addressed this Association three years ago, has published the results of 300 cases occurring in the Canadian Army in England. One of his important conclusions is that early and adequate fixation invariably resulted in fusion. My belief is that the knowledge of the frequent occurrence of fracture of the carpal scaphoid in young males and the necessity of early recognition and adequate early treatment by prolonged and proper fixation will eliminate the problem in which we originally were so much interested,—namely, the treatment of ununited fractures of the carpal scaphoid. That, as Dr. Meekison said, is a difficult problem, but it can be eliminated as a problem by early recognition of fresh cases and their adequate treatment.

Major Joseph E. Milgram, Clinton, Iowa: I would like to confine my remarks to the difficult group of cases—non-union of the carpal scaphoid—and suggest a new procedure, which by this time, possibly, is being performed by a number of us, all unknown to one another.

I have difficulty in fixing properly the small proximal fragment with a cortical avascular osseous graft. Consequently, in 1936, I commenced to denude the dorsal aspect of both fragments, hollowing them, particularly the proximal one, and packing the continuous cavity so created with cancellous bone. Originally, I removed the packing bone with a hollow punch from the greater trochanter of the femur, using a stab wound for the purpose. More recently, the bone has been obtained through a hinged trap door beneath the crest of the ilium. After hollowing the fragments with drills of increasing diameters, curettes, and slow-speed dental burrs, and packing them with bone, I have preferably not closed the avascular capsule over the site of implantation, but have simply closed the subcutaneous tissue. The gripping position compresses the cancellous plug. I have had the opportunity of doing only ten cases, nine of which have united with a bony bridge across the gap. In one, aseptic necrosis of the proximal fragment has persisted. So much for this small group.

Incidentally, I have not been convinced that every non-union of the carpal scaphoid merits intervention Sometimes, I think we are influenced too much by roentgenographic findings. I have seen a symptomatic non-union of the carpal scaphoid persist without arthritis; and, in another case of non-union, I have observed apparent union occur years later, spontaneously. Furthermore, at operation for old non-union, the articular cartilage has often shown little or no evidence indicative of the presumably inevitable arthritic changes prophesied. Often, there is little correspondence between roentgenographic appearance and function.

Dr. D. M. Meekison, Vancouver, British Columbia, Canada (closing): Dr. Milgram, I do not think one-grafting for non-union is always necessary. I have seen more than one patient with a completely ununited scaphoid, who has completely normal function. One was my own radiographer in England. He has full use, although he had complete non-union.

INTERNAL DERANGEMENTS AND FRACTURES INVOLVING THE KNEE

Results of One Hundred and Fifty Consecutive Arthrotomies Performed at a Station Hospital

BY MAJOR WILLIAM F. STANEK

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Injuries to the knee, both recent and old, constitute one of the major problems of orthopaedic surgery in the Army. As a result, there is much discussion of the advisability of performing surgery for internal derangements, especially those which have existed prior to the soldier's entry into the Service. Some surgeons assert that few soldiers so operated upon return to full duty.

Knee surgery can be performed by competent surgeons under the conditions found in a well-run operating room, without undue danger to the patient. Under no other circumstance is any elective surgery justifiable. In the cases reported, there was no instance of infection, and no patient was subjectively worse following operation. Full motion has not been regained in all cases of fracture, and, in one case, in which a hemangioma was removed, there was marked loss of flexion. The routine use of a narrow Esmarch tourniquet resulted in two transient paralyses.

The criticism that these men do not return to duty is difficult to answer. The patients whose cases are reported have been followed closely during their stay at Camp Crowder. Further follow-up has been difficult, but has been successful in many instances. Where it is probable that the man has been discharged from the Service, because of change in regulations, this fact has been noted in the tables. The last patient in the series was operated upon four months prior to the writing of this paper, and the longest detailed follow-up has been twenty-one months. The "follow-up" given in footnotes to each table is the average length of time in all cases between operation and the last recorded hospital visit or discharge from Service. The review showed that when both patient and surgeon were satisfied with the result, the check-up visits were few. When the result was unsatisfactory to the medical officers, especially when the man also was dissatisfied, overseas clearance could not be given, suitable duty assignments were difficult to find, and the follow-up rose from 3.2 months in Class I to 12.5 months in Class IV.

Surgery in the Army has been likened many times to civilian compensation work. This does not give a true picture of the prevailing conditions. The discrepancy between the results obtained in private practice and in insurance practice is explained by the desire of the patients in the latter group to obtain money without working for it, and failure to recover is thought to be due to their hope of receiving a cash settlement. Continuance of pay while in the hospital may prolong a soldier's convalescence, but I do not believe that many soldiers, while under treatment, give thought to later claims against the Government. They may, however, desire discharge from the Army, and frequently fall back on their operation as a means of obtaining discharge or of avoiding distasteful duty.

To properly appreciate the final results in these cases, it must be realized that they have been reached under changing regulations and directives. It can readily be seen that fluctuating physical standards operate to permit the discharge of certain of the men on whom knee surgery has been performed, and their loss from the Service should not be charged to the surgery done. Those patients marked on the tables "discharged as unskilled" had all been previously classified for limited duty only.

One hundred and fifty arthrotomies have been reviewed. These cases have been divided into six classes, in order that they might be more readily evaluated. The first seventy-five cases were originally tabulated in January of 1943, and included the patients

operated upon between April and December 1942 (Group 1). On the basis of the results obtained, certain changes were made in the type of case considered for operation. The second series of patients were operated upon between January and October 1943 (Group 2). By showing the first and second seventy-five cases separately, it is hoped to emphasize this change. The more interesting and unusual cases have been briefly abstracted.

A few technical considerations should be emphasized. In every case, exploration of the anterior chamber of the knee has been continued until definite pathological changes have been located, or a thorough examination has been completed. Negative, as well as positive findings, have been recorded on the operative sheets, a fact of considerable importance in the later evaluation of several of the cases. Where a meniscus has been removed, as much of it has been taken out as could be obtained through an anterior incision. When it has been thought that the remaining portion might cause later difficulty, a Henderson incision has been used to obtain the remainder of the meniscus. In simple cases of injury to the meniscus, sheet wadding and muslin dressings have been applied, quadriceps-

TABLE I

CLASS I. MAJOR CHANGES IN SOFT TISSUE

Location of Injury	Case No.	No. of Cases	Disposition
Group 1[1] (Cases 1 through 75)			
Injury to the meniscus		23	Full duty
	25	1	Discharged as psychoneurotic
	38	1	Disability discharge
	40	1	Overage discharge
	63	1	Limited duty
Injury to the meniscus and hypertrophy of the fat pad		3	Full duty
Injury to the meniscus and rupture of a cruciate or collateral ligament		6[2]	Full duty
	29	1	Discharged as unskilled
	50	1	Limited duty
Injury to the meniscus and mild arthritic change		5	Full duty
	37	1	Discharged as unskilled
	23	1	Discharged as unskilled
Injury to the ligaments or fat pad, without damage to the meniscus	27	1[3]	Limited duty
	47	1[4]	Full duty
Group 2[5] (Cases 76 through 150)			
Injury to the meniscus		39[6]	Full duty
	135	1	Discharged as psychoneurotic
Injury to the meniscus and hypertrophy of the fat pad		11[7]	Full duty
	112	1	Disability discharge
Injury to the meniscus and rupture of a cruciate or collateral ligament		5[8]	Full duty
Injury to the ligaments or fat pad, without damage to the meniscus	132	1[4]	Duty[9]

[1] The postoperative follow-up of the patients returned to duty was 3.6 months; the postoperative follow-up of those who were on limited duty or were discharged was 7.1 months.

[2] These cases include one case of tear of the posterior cruciate ligament, one incomplete and three complete ruptures of the anterior cruciate ligament, and one of moderately relaxed tibial collateral ligament.

[3] In this case, there was a tear of the anterior cruciate ligament only.

[4] In this case, there was hypertrophy of the fat pad only.

[5] The postoperative follow-up was 3.2 months.

[6] In one case, calcification was present in the region of the tibial collateral ligament.

[7] The fat pad was removed in five cases.

[8] These cases include one case of relaxed fibular collateral ligament, one case of relaxed tibial collateral ligament, and three cases of complete rupture of the anterior cruciate ligament.

[9] The soldier, although not reclassified, is known to be in a job not requiring maximum use of the knee.

setting exercises have been started on the first postoperative day, and the man has been allowed up without crutches as soon as he could raise his leg unassisted from the bed. This has frequently been on the second or third postoperative day. No attempt has been made to repair torn cruciate ligaments.

A few typical cases from Group 1, Class I, follow:

Case 25. The patient, aged twenty-five years, entered the hospital with an acutely swollen knee. He gave no history of injury prior to entry into the Service. Flexion was blocked, and, on operation, a tear in the posterior quadrant of the medial meniscus was disclosed. He regained full motion, and had only 0.6 of a centimeter (one-quarter of an inch) of atrophy of the thigh. In spite of the original history given, he later asked the surgeon to sign papers which would support a claim that he had been injured at his last place of civilian employment. He refused to do duty, and was referred to the psychiatrist to determine whether he was psychoneurotic or a malingerer. He was discharged under the former diagnosis.

Case 38. The patient, aged thirty-six years, was injured in the Army. The lateral meniscus, which was torn in the posterior quadrant, was removed. An operative note said, "slight fraying of the articular surfaces". Full motion was obtained; there was no swelling, but there was 1.25 centimeters (one-half of an inch) of atrophy. Subsequently he continually complained, and the Disposition Board granted a disability discharge, because of the operative note, making a diagnosis of early arthritis. (From the surgeon's standpoint, this patient had a good result.)

Case 63. The patient, aged thirty years, had a definite history of knee injury, and a bucket-handle tear of the medial meniscus was found on operation. Six months after operation, there was no swelling or limitation of motion in the knee, and no atrophy. He had many complaints of pain in both knees, and was given a limited-service classification, as a means of getting him into work he liked better. A subsequent change in regulations made this man available for full duty.

Case 50. The patient, aged twenty-four years, injured his knee in 1940, while in Service. Both menisci and the anterior cruciate ligament were torn. There was mild arthritic change. He was of value as an instructor, and is of such character that he will carry out his duties in spite of disability. His condition was improved by operation. Limited service was recommended to permit his continuing as an instructor.

The lessons taught by a review of the first group of cases are rather striking. Of forty-seven patients in Class I, six were discharged, while three more, reclassified to limited duty, might have been discharged, if the commanding officers had desired, on non-medical grounds (as unskilled or unable to do a full day's work). It was evident that men having meniscus injury only *do* return to full duty. When the man is anxious to continue as a soldier, there is no difficulty. When he is inclined to shirk, he can be kept at duty as any other individual with no objective findings but many complaints, provided exploration of the knee has been thorough, so that the surgeon is certain no pathological changes have been overlooked.

Where more than injury to the meniscus is found, the difficulty in keeping a man a duty increases. Those with tears of the cruciate ligaments can be returned to duty but where damage to the collateral ligaments or mild arthritic change is diagnosed preoperatively, operation is warranted only if the man is of military value and has a marked desir to be a soldier. Otherwise, in spite of operative improvement, he will probably be eligibl for a discharge at some time. If a man with a knee of this type continues to complain, th surgeon cannot in honesty force him to duty.

In the second group of cases in Class I, fifty-six out of fifty-eight patients returned t duty. Two cases are of interest.

Case 93. The patient, aged twenty-four years, had been injured while playing football. At a previou operation the medial meniscus had supposedly been removed. He complained of pain and "popping" in th knee. He had drawer-forward sign, a mildly relaxed tibial collateral ligament, and a palpable mass in th posteromedial part of the knee, which was thought to be the back half of the previously partially remove meniscus. At operation, an entire meniscus (not believed to be regenerated), showing a tear, was removed and the tibial collateral ligament was plicated. Because of complaints of pain, he was given limited duty Later he was seen by three officers at a swimming pool. For an hour and a half he did fancy dives, acted a understander for another man to dive from his shoulders, and finally did tricks in the trapeze rings, hanging from heels and knees. Seeing one of the officers at the end of the performance, he admitted the knee was fit for full duty, and he has not returned since.

TABLE II

CLASS II. MAJOR PATHOLOGICAL CHANGES IN BONE OR ARTICULAR CARTILAGE

Condition	Case No.	Associated Pathology: Loose Bodies	Torn Meniscus	Arthritis	Tear of Cruciate Ligament	Osteochondritis	Disposition	Comment
Group 1[1]								
Osteochondritis dissecans	18	1		Yes			Full duty	A sergeant with a keen desire to do duty.
	28	2	Yes				Full duty	
	56	1					Duty[4]	
	60	3					Limited duty	One body left in posterior compartment.
Erosion of under side of the patella (chondromalacia)	24						Discharged as unskilled	
	36	4	Yes				Duty[4]	Patella not smoothed.
	44	4					Duty[4]	Patella smoothed.
	42						Full duty	Only a slight roughening of patella.
	64		Yes				Disability discharge	Not improved by operation; patella not smoothed.
	66		Yes				Full duty	Patella smoothed.
	67	6					Duty[4]	One loose body missed; no attempt was made to remove one in popliteal space.
	75		Yes				Full duty	Only slight roughening of patella.
Loose body (removed without thorough exploration)	34						Full duty	
	65						Full duty	
Osteochondroma protruding into the knee	26		Yes				Duty[4]	
Group 2[2]								
Osteochondritis dissecans	86	1					Duty[3]	Loose body removed; no complaint about knee. Unofficial information indicates he received overage discharge at another camp.
	94	1					Full duty	Loose body removed.
	96						Limited duty	Area of recent destruction.
	128	1					Full duty	Patient says "knee perfect".
	145	1					Full duty	
Erosion of under side of the patella (chondromalacia)	82	1	Yes		Yes		Limited duty	Patella smoothed and meniscus removed.
	95	1	Yes		Yes	Yes	Duty[4]	A sergeant of extreme value to his company.
	125						Duty[3]	
Osteochondroma protruding into the knee	121						Full duty	

[1] Postoperative follow-up of the patients returned to duty was 4.3 months; the postoperative follow-up of those who were on limited duty or were discharged was 8.0 months.
[2] Postoperative follow-up was 5.2 months.
[3] The patient has probably been discharged, but no record is available.
[4] The soldier, although not reclassified, is known to be in a job not requiring maximum use of the knee.

CASE 112. The patient, aged twenty-one years, complained chiefly that his knee locked and popped. He gave no history of difficulty prior to entering the Army. There were no physical findings except 0.9 of a centimeter (three-eighths of an inch) of atrophy of the thigh. A medial meniscus, with a loose anterior end, and a hypertrophied fat pad showing areas of calcification were removed. Postoperatively, a popliteal cyst appeared. He continued to complain of the cyst and also of cardiac pain. Because of his general attitude, further operation was believed inadvisable. He was transferred to a general hospital, and received a disability discharge because of the popliteal cyst.

One factor in the results is not apparent. During the period that this second group was under treatment, a Reconditioning School was set up. The patients with knee injuries were subjected to intensive physiotherapy, designed primarily to actively build up the quadriceps. During the course, military drill was stressed, and, in the final two weeks, the men went over a difficult obstacle course. During their last week, they marched a minimum of fifty miles. The man did not return to his unit until six or eight weeks after operation. Unless a soldier could produce objective findings, he had difficulty in convincing the surgeon he could not do duty, if he had completed this course.

Review of the cases in Class II is of especial interest (Table II).

CASE 64. The patient, aged twenty-one years, gave a history of pain and swelling of the knee, which developed after he had entered the Army. Operation revealed hypertrophy of the fat pad, tear of the medial meniscus, and marked chondromalacia of the patella. The patella was not smoothed. He regained full motion, but later complained of pain in both knees. He felt he was not made worse by the operation, but was not improved. After adequate trial at duty, in which he cooperated fully, he was granted discharge for disability.

CASE 67. The patient, aged twenty-six years, had injured the right knee, playing football, at the age o sixteen years. There had since been intermittent swelling and pain. Roentgenograms showed five loos bodies in the suprapatellar pouch and one in the popliteal space. At operation, marked chondromalacia o the patella was found. The loose bodies were in distinct pockets in the suprapatellar pouch. The patella wa smoothed, and four loose bodies were removed; the last one in the anterior chamber could not be located The patient returned to duty, and complained only of occasional catching. One year later, a second attempt was made to locate the final loose body in the anterior chamber, but it slipped into the posterior chamber. At operation, roentgenograms taken with a portable machine did not locate it, and it has given no furthe trouble. Exploration showed the patella to be smooth, and the cartilage to be of good color and well regenerated, with no evidence of chondromalacia. No evidence of damage to adjacent femoral cartilage was found.

CASE 96. The patient, aged eighteen years, had an operation to remove an area of recent osteochondritic involvement from the bearing surface of the femur. Subsequently he complained of inability to drill. An attempt was made to discharge him as being below the minimal standards. Because of his value as a secretary, he was retained in Service, but was not required to drill or do other physical work. Recently, his commander stated that he did not see why there had been so much fuss to keep this man from doing physical work, since in the evening he was one of the outfit's best basketball players.

CASE 125. The patient, aged nineteen years, had chondromalacia of the patella only. Operation produced no subjective improvement. He was from the Air Corps, and was returned to his own field in the hope that work which interested him would be found. He had full motion of the knee and no swelling. It is believed that this man will ultimately receive a discharge.

Return to duty of the first four patients with osteochondritis dissecans was believed better than could be expected from a larger series. The continuance of good results was a gratifying surprise. With the exception of the patient with the acute case, all these men preoperatively were carrying on full duty, with a complaint only of catching due to a loose body. The old irregularity of the articular surface appeared to be of minor importance. In the light of our present knowledge, these cases will continue to be treated by surgery.

It is an old cliché that anything can be proved by figures. The cases in Class II, grouped under "erosion of the under side of the patella (chondromalacia)", are the only glaring instances where the separation of this series into classes distorts the results. Actually no case was diagnosed preoperatively as chondromalacia of the patella. Swelling and pain, coupled with the finding of tenderness on tapping the patella or pressing around its edges, have often suggested the diagnosis, as has grating on patellar movement. The diagnosis before operation has usually been a torn meniscus or a loose body. In the eleven

TABLE III

CLASS III. CASES SHOWING SEVERE ARTHRITIS[1]

Case No.	Associated Pathology: Loose Bodies	Associated Pathology: Torn Meniscus	Associated Pathology: Cruciates Torn	Disposition	Comment
Group 1					
39	3			Limited duty[2]	Loose bodies removed.
45				Limited duty. Discharged as unskilled	Old fracture of the patella; patella removed. Some lessening of pain on movement.
70	12	Yes	Yes	Discharged as unskilled	Slightly improved by operation. Meniscus and loose bodies removed.
71	1	Yes	Yes	Discharged as unskilled	Menisci and loose bodies removed; full motion present.
Group 2					
97				Disability discharge	Arthritis of the patella and femur; adhesions of fat pad to tibia. Patella smoothed and fat pad removed. Patient had a mild tourniquet paralysis. Final result, no essential change from condition before operation.

[1] The postoperative follow-up was 4.5 months.
[2] This patient has probably been discharged, but no record is available.

cases, six have shown meniscus injury; five, including three with injury to the meniscus, have had loose bodies; and in only three has the patellar defect been the only finding. Eight patients remain on duty, while one other, listed as on duty, will probably be discharged.

These cases are difficult to evaluate. I believe this condition is more often an accompaniment of old knee injuries than has been generally reported. In spite of the fact that two-thirds of our patients are still on duty, I do not believe that, if a preoperative diagnosis of chondromalacia of the patella is made, the operation should be done in the Military Service. If the condition is found at operation, the patellar cartilage should be smoothed. Removal of the patella is not a suitable procedure in the Army. Regardless of the result obtained, it is probable that the psychological effect would preclude the returning of most men to duty.

Table III, summarizing the cases in Class III, is self-explanatory. A man having arthritis of the knee of more than minimal severity cannot perform military duty. Each of these men had undergone combat training and had entered the hospital with a completely disabled knee. In each instance, the condition was undeniably aggravated in Service, and operation was undertaken to obtain the maximum benefit of hospitalization. The fact that not one of these five men is believed to be now in the Service is a warning of the danger of inducting a man with an arthritic knee.

The results of treatment in the few cases of fracture in the region of the knee joint show the difficulty experienced in returning men with these fractures to duty, especially those with fractures of the tibial plateau (Table IV). The failures are not entirely explainable on the basis of the injury alone. Wherever it has been necessary to immobilize a knee postoperatively for any length of time, atrophy of the thigh and limitation of motion have been the result. It has not been felt that the limitation has been sufficient in any

TABLE IV

CLASS IV. FRACTURES

Group 1[1]

Case No.	Type of Fracture	Disposition	Comment
2	Tibial spine	Duty [3]	Held with vitallium screw.
8	Tibial plateau	Disability discharge	Patient also had peroneal-nerve injury. Plateau held b screw. Arthritis developed. Foot-drop persisted.
30	Tibial spine	Duty [3]	Fragment sutured in place. Tourniquet paralysis devel oped. Excellent recovery.
31	Tibial spine	Limited duty	Fragment sutured in place. Patient has limitation o flexion to 75 degrees, and marked atrophy of thigh.
51	Compound fracture of patella	Disability discharge	Small, lower-pole fragment removed. Patient also ha compound fracture of the ankle. Discharge was grante for this, not for knee.
74	Medial plateau of tibia	Disability discharge	Fixation by screw. Patient had many complaints. Ther was full extension, flexion to 75 degrees. Roentgeno-grams showed mild traumatic arthritis.

Group 2[2]

Case No.	Type of Fracture	Disposition	Comment
76	Fracture of the medial plateau with dislocation of the knee	Disability discharge	Good reduction, but marked loss of motion. Fixation by screw.
80	Fracture of the patella	Duty [3]	Patella was wired; it was refractured at seven weeks in a fall from the bed and required rewiring.
89	Old fracture of patella with malunion	Full duty	The lower fragment (one-fourth of the bone) was removed.

[1] The postoperative follow-up of the patients was 12.5 months.
[2] The postoperative follow-up of the patients was 7 months.
[3] The soldier is known to be in a job not requiring maximum use of the knee.

instance to warrant quadricepsplasty, but, in several instances, it made return of the patient to duty difficult or impossible, in spite of prolonged physiotherapy. Case 74 illustrates other factors complicating the results.

CASE 74. The patient, aged forty-two years, had been in Service two months when he fractured the medial table of the tibial plateau in a twelve-foot fall from a pole. This man had had no previous pole-climbing experience. The meniscus was removed, and a screw was used to hold the tibial plateau in place. He obtained full extension and flexion to 75 degrees. There was 2.5 centimeters (one inch) of atrophy of the thigh and no lateral instability. Roentgenograms showed an excellent reduction. This man was a model hospital patient, but, on return to duty, he became a disciplinary problem. I believe his age and fear of further injury, as well as residual disability, underlay his difficulties. A man desirous of continuing in the Service would have done duty with the knee condition present. In this man, however, the disability was sufficient basis for a disability discharge.

Few purely exploratory operations have been done (Table V); fewer should be done in the future. Exploration in each case was thorough, and the one patient granted a disability discharge did have considerable difficulty clinically. The three patients marked "duty" are not good soldiers. They have been seen many times with many complaints. Probably one man (Case 22) would have been under treatment in civilian practice. These patients illustrate how frequently psychoneurosis is found in the Army, and the necessity of making as definite a diagnosis as possible before operation. If a diagnosis cannot be made, disposition should be accomplished without exploration.

In Class VI are grouped the cases which might be called unusual. Careful watch

TABLE V

CLASS V. EXPLORATORY OPERATIONS [1]

ase No.	Complaint	Finding	Disposition	Comment
Group 1				
43	Indefinite knee complaint	None	Duty [2]	Exploration only. Patient has had no further knee complaints, but has been in hospital since for stomach complaints There were no organic findings Diagnosis was mild neurosis
13	Right knee "comes out of place"	Relaxed anterior end of lateral meniscus	Full duty	Meniscus was removed. There were no objective findings, but patient still says something "comes out" on lateral side.
22	Knee cap "pops" out of place	Torn medial meniscus	Disability discharge	Meniscus was removed, and Campbell's operation was performed to prevent possible dislocation of the patella Patient cooperated, but knee continued to swell at intervals. Dislocation was never demonstrated, but there was much grating of the knee Condition was essentially unchanged by operation Patient was discharged because of mild, symptomatic arthritis.
Group 2				
116	Locking knee	Questionable tear of medical meniscus	Full duty	Meniscus was removed and knee was explored He later complained of hip pain, but there were no findings The final diagnosis was mild psychoneurosis.

[1] Postoperative follow-up was 12 months
[2] The soldier is known to be in a job not requiring maximum use of the knee

TABLE VI

CLASS VI UNUSUAL CASES [1]

ase No	Complaint	Findings	Disposition
85	Both knees painful, right knee locks	Fibrous mass, 5 by 1 8 × 1 8 centimeters, loose in the intracondylar area of the right knee, left knee was negative	Limited duty
106	Mass in region of lateral ligament	Fibrous mass, 2 by 1 5 × 1 0 centimeters, attached to the lateral meniscus	Full duty
117	Tumorous mass beneath the patella The mass was painful (Patient had had 2 previous operations)	Hemangioma involving the fat pad and invading the patellar ligament	Full duty [2]

[1] Postoperative follow-up was 3 4 months
[2] The soldier was on full duty when he left Camp Crowder, but the author doubts that he will be able to do full duty

has been kept for discoid cartilages, cysts of the cartilage, and tumors of the synovial membrane

CASE 85 The patient, aged nineteen years, complained of pain in both knees and locking of the right one A white, sausage-shaped mass was removed from the right knee, it was not attached to the synovial membrane Clinically, it appeared fibrous, but, on microscopic examination showed cartilage and fibrous tissue The knee was otherwise normal Exploration of the left knee was carried out because of the findings in the right No abnormality was found

CASE 106 The patient, aged nineteen years, gave a history of severe twisting injury to the knee, which

had occurred six years before operation and had kept him in bed for one month. He complained of swelling on the lateral aspect of the knee. On examination, there was a hard mass in the region of the fibular collateral ligament, and, in the roentgenograms, a wide interspace was noted on the lateral side. At operation, a fibrous mass 2 by 1.5 by 1.0 centimeters, found attached to the lateral meniscus, was removed, together with the meniscus. Six months later, he had slight swelling of the knee, full motion, no atrophy, and no abnormal mobility. In the pathological examination, unfortunately, the mass was ignored, and only the findings in the meniscus were reported.

CASE 117. The patient, aged twenty-four years, had had a tumor removed from the region of the left knee at the age of six years. This had recurred and had been again removed at the age of thirteen years. Thereafter, swelling had appeared whenever the knee was bruised. On examination, there were two operative scars medial to the patella, and a swelling, which felt cystic, was noted in this area. A larger mass could be felt beneath the patella. At operation, the tumor was found to involve the old scar and the fat pad, and to have infiltrated the patellar tendon. Except for a small portion in the tendon, which could not be obtained without removal of the tendon, the tumor was removed completely. A defect in the capsule, 2.5 centimeters (one inch) square, was created, which could only be closed with a free fascia graft. The cast was removed after thirty days. Five months after operation, the patient had full extension, and flexion to 95 degrees. The only excuse for this operation was that the man appeared to be of military value. He returned to duty in spite of his residual disability.

SUMMARY

In 150 consecutive knee arthrotomies, 105 cases showed injury only to the menisci, ligaments, or fat pad. Eighty-six torn medial menisci and fifteen torn lateral menisci were removed. Two cases showed tearing of both menisci. Fifty-four bucket-handle, twenty anterior, ten posterior, and three minimal tears (loose anterior attachments) are recorded. In the remaining cases, no accurate description of the portion of the meniscus injured is recorded. In this group of patients, ninety-seven returned to some type of duty.

In twenty-four cases, disorders of the bone and articular cartilage were shown. Of nine patients with osteochondritis dissecans, eight are believed at duty, while of eleven patients with chondromalacia of the patella, eight are probably still in Service.

Only five patients with severe arthritis were operated upon, and none of them are believed to be in the Army at present.

Nine patients with recent or old fractures involving the patella, tibial spine, or tibial plateau were operated upon. Five of these men have been returned to duty. Three men with fractures of the tibial plateau have been discharged for disability. The last man of the group was discharged for an ankle disability.

Of the remaining patients in the series, those operated upon primarily for diagnosis have shown poor results, the final diagnosis in most cases being psychoneurosis. Three unusual cases were found, and have been described in detail.

CONCLUSIONS

Patients with tears of the menisci, I believe, are suitable for operation in the Army, and a high percentage of these patients return to duty. The presence of injury to a cruciate ligament does not markedly alter the recovery rate, but the presence of injury to one of the collateral ligaments, or of chondromalacia of the patella gives a poor prognosis. Where diagnosis of these latter conditions is made preoperatively, operation should not be undertaken in the Military Service.

Cases showing loose bodies are suitable for operation, provided the only articular defect noted is that of an old osteochondritis dissecans. The presence of arthritis of the knee of any degree, shown either clinically or by roentgenogram, makes it unwise to operate, unless the man is of extreme military value.

Fractures of the tibial plateau offer a poor prognosis as to return of the soldier to military duty.

Finally, it is my conclusion that the majority of our mistakes have arisen from overenthusiasm and from lack of appreciation of the rigors of military service to which a man must return.

A METHOD FOR STUDYING HEALING OF BONE *

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INTRODUCTION

The methods commonly used in studying the healing of bone leave much to be desired. Studies employing roentgenograms, histological sections, clinical impressions, the experimental breaking of bones, *et cetera*, have added to the understanding of the healing of fractures, but each method has certain disadvantages.

In order to study better the metabolism of strontium and phosphorus in healing bone, radiostrontium† (Sr^{89}) and radiophosphorus† (P^{32}) were used. Radiostrontium was chosen, because, in the Periodic Table, it is closely related to calcium and behaves physiologically in a manner similar to that substance, but, for technical reasons, is more convenient to use than radiocalcium (Ca^{45}). Chemically and physiologically, radiostrontium and radiophosphorus behave identically with the non-radio-active substances, and have the advantage that they can be used in "tracer" doses,—that is, in amounts that can be identified readily, but do not influence normal physiological processes. Both radiophosphorus and radiostrontium give off beta particles of approximately the same energy value, which can be measured easily with a Geiger-Müller counter.

Methods were devised to determine the uptake of phosphorus and strontium by healing bone, by means of which it was possible to study the changes in the mineral metabolism from day to day, the relationship between phosphorus and strontium, and the effects of age on the healing of bone. These investigations were made *in vivo* on rats; with certain modifications they could be applied to studies on the healing of bone in man.

Cohen and Greenberg studied the uptake of radiophosphorus by bone in rats, particularly in relation to vitamin D_1. Treadwell and her associates studied the uptake of radiostrontium by normal and malignant tissues in human beings, and found that the strontium was retained wherever new tissue was being formed. Pecher showed that strontium, like calcium, is concentrated in the skeleton. The relative amount of radiocalcium and radiostrontium in bone and muscle was approximately the same for both elements, although the retention of calcium was greater than that of strontium. He found that, in mice, radiostrontium and radiophosphorus were taken up by normal bone in the ratio of 2.3 to 1, which is in close agreement with the mean ratio of 2.6 to 1, found in our studies of adult rats (Table I). The rate of calcification in the healing of fractures in guinea pigs and rats has been studied by histological methods by Hertz and by Urist and McLean.

METHODS

Attempts to produce uniform fractures of the tibia of the rat proved unsuccessful. It was found, however, that uniform defects in the tibia could be obtained by the use of a motor-driven circular saw. An incision from 2 to 4 centimeters in length was made in the skin of the outer surface of the leg, parallel to the tibia, and the skin was dissected away from the fascia covering the muscle until the tibia was exposed. By sharp dis-

* The work described in this paper was done under a contract recommended by the Committee on Medical Research between the Office of Scientific Research and Development and the University of California.

† The terms radiostrontium and radiophosphorus are used in place of the more lengthy terms radio-active isotope of strontium or phosphorus or radio-active strontium or phosphorus.[4]

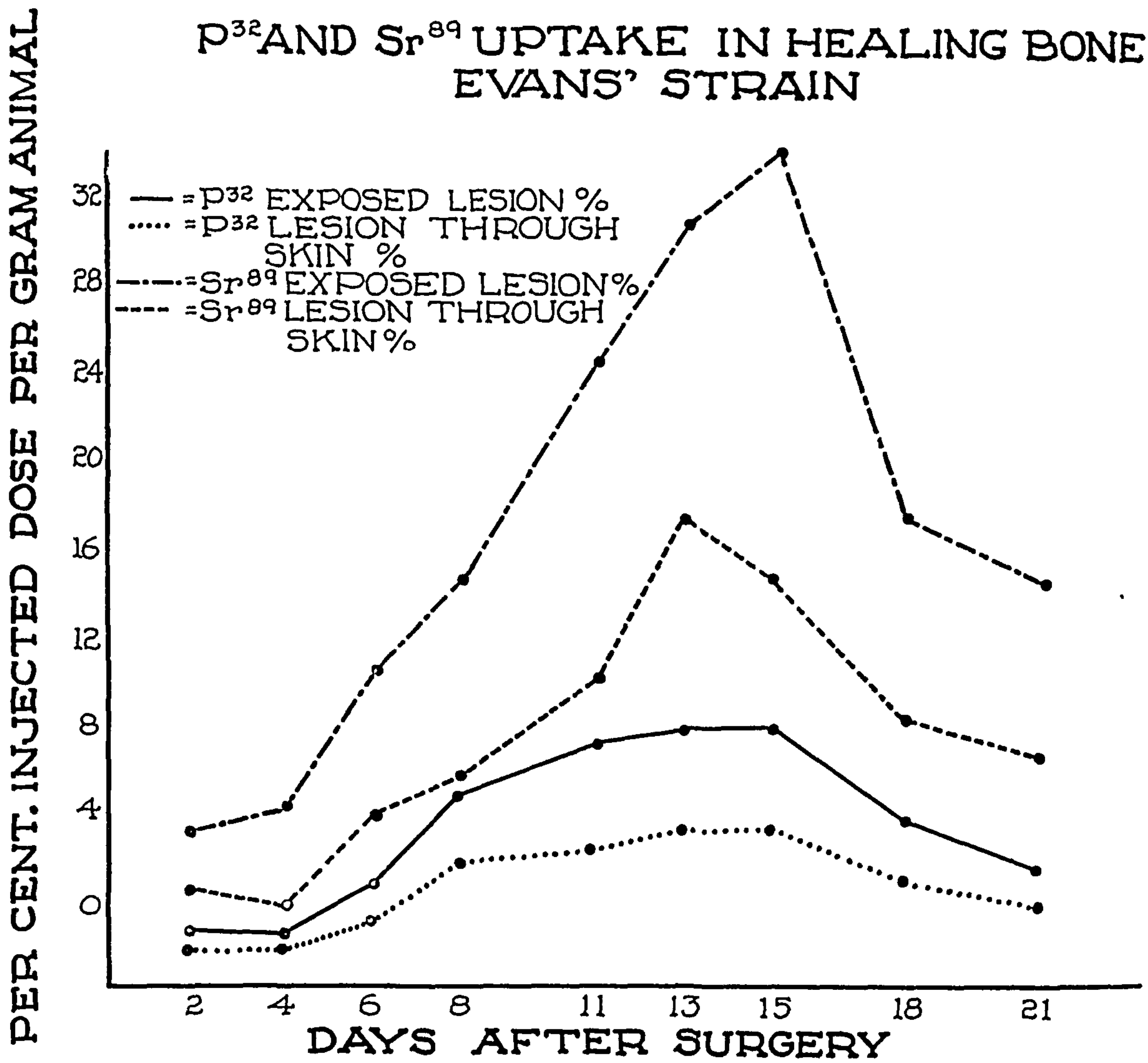

FIG. 1

section, the anteromedial aspect of the bone was then cleaned of muscle. With the saw, which was 6 millimeters in diameter by 0.75 of a millimeter in thickness, a cut was made, parallel to the long axis of the tibia, in the middle of the anteromedial surface, with the center of the cut at the level of the tibial tuberosity. Depth was controlled by allowing the saw to penetrate until its axis touched the surface of the bone. The distance from the shaft to the perimeter of the saw was 2 millimeters, so that the depth of the cut made was somewhat less than 2 millimeters. The cut extended through the marrow, but not into the cortex on the opposite side. The wound was cleansed of debris by irrigation with sterile saline or Ringer's solution, and the skin was closed with a continuous suture. After recovery from anaesthesia, the animals walked without apparent discomfort. In all cases, the radio-active solution (radiophosphorus as sodium acid phosphate or radiostrontium as strontium chloride) was given intraperitoneally 24 hours before measurements were made.

To shield the Geiger-Müller counter from beta particles other than those originating in the wound or its immediate vicinity, a lead plate with an aperture, 2 by 5 millimeters, was placed on the leg over the position of the wound. Some practice is needed in locating the bony lesion through the skin, although it usually can be felt either as a depression in the early stages, or as a slightly raised callus later. Several readings were taken, the lead shield being removed and reset each time to check for accuracy of the readings. The incision was then opened, the skin was retracted to expose the bone lesion, and the readings were taken with the aperture directly over the lesion. Similar readings were taken over the normal contralateral tibia.

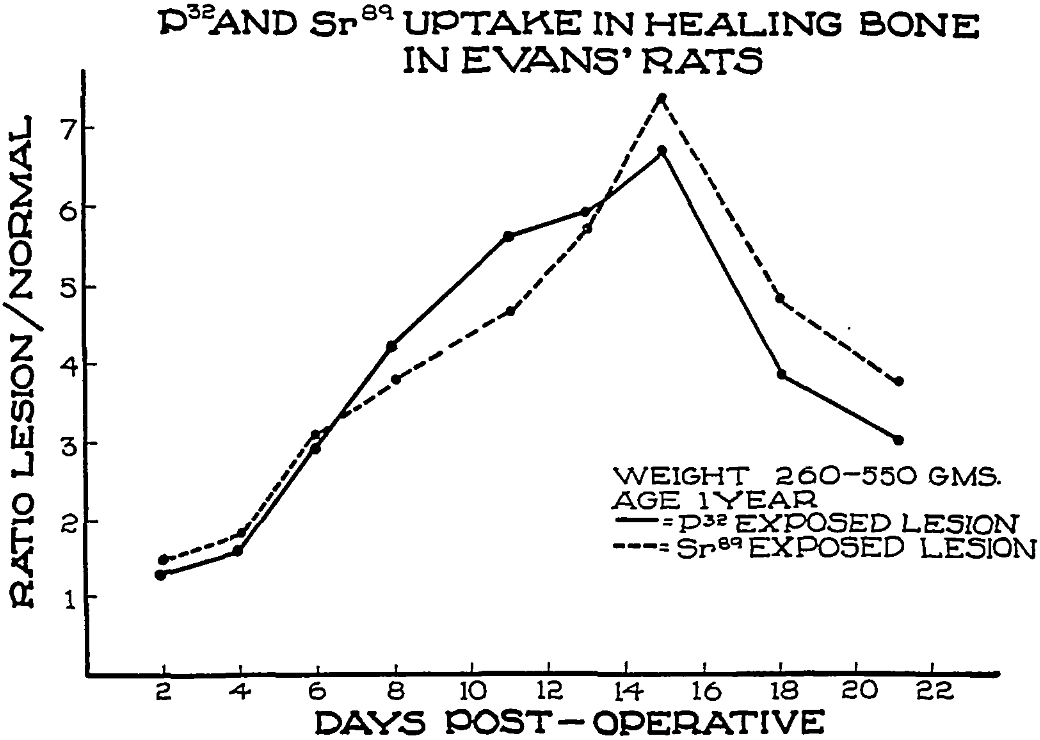
P32 AND Sr89 UPTAKE IN HEALING BONE IN EVANS' RATS
RATIO LESION/NORMAL
1
2
3
4
5
6
7
WEIGHT 260-550 GMS.
AGE 1 YEAR
= P32 EXPOSED LESION
= Sr89 EXPOSED LESION
2
4
6
8
10
12
14
16
18
20
22
DAYS POST-OPERATIVE

FIG. 2

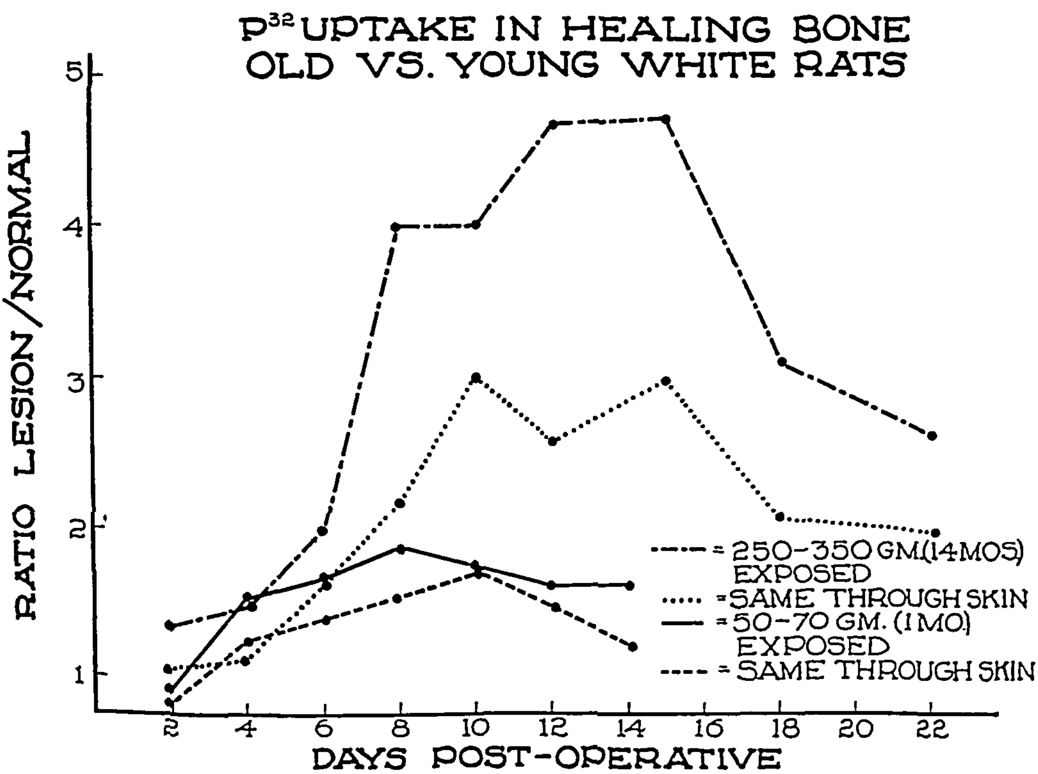
P32 UPTAKE IN HEALING BONE OLD VS. YOUNG WHITE RATS
RATIO LESION/NORMAL
1
2
3
4
5
= 250-350 GM.(14 MOS) EXPOSED
= SAME THROUGH SKIN
= 50-70 GM. (1 MO) EXPOSED
= SAME THROUGH SKIN
2
4
6
8
10
12
14
16
18
20
22
DAYS POST-OPERATIVE

FIG. 3

P^{32} has a half-life of 14.3 days, and Sr^{89} of 55 days. Allowance is made for this difference in calculations of the radio-activity in the lesion and in the normal bone as percentage of the injected dose per gram. Radiation effects on tissue are considered negligible, because of the small dose and the short time interval (24 hours) between injection and measurement. In experiments where the radio-active elements are in the tissue for more prolonged periods, such effects may have to be taken into account.

The Geiger-Müller tube used for measuring the radio-activity was completely sealed in glass and had a thin glass window approximately 5 centimeters (2 inches) in diameter. It had a 400-volt plateau which assured independence of fluctuations in the line voltage. A scale of eight counting circuit was used, and the eighth pulse from the tube activated a mechanical counter, so that the counts for each reading were automatically recorded. Before the tube was used in the experiments, it was checked with a cathode-ray oscillograph for uniformity in amplitude and for shape of the discharges (pulses). To minimize the amount of stray radiation (background), the tube was mounted inside a box with lead walls 5 centimeters (2 inches) thick. The lid and one side wall were hinged, so that the box could be opened at the side and top to introduce the animal and to orient the counter over the lesion or bone. Inside the box, the tube itself was encased in a brass cylinder, with walls 0.3 of a centimeter (1/8 of an inch) thick, to protect it from radiation originating from portions of the animal other than the region under investigation. The brass cylinder was mounted on a rack and pinion, so that it could be raised and lowered or fastened at any one position by the adjustment of a pair of knurled knobs. As previously mentioned, a lead plate was used to admit radiation into the counter window only from the 2-by-5 millimeter aperture over the lesion or normal bone. The anaesthetized rat was held on a block of wood, with the lead plate in position over the lesion. The block was then oriented, so that the aperture in the lead plate was centered under the counter; the cylinder holding the counter was then brought down in contact with the plate; and readings were taken.

Background readings were always taken before and at the end of the readings from the animals. These readings agreed to within a few per cent., and amounted to about 30 counts per minute. As a precaution against the possibility of a change in its characteristics, the tube was checked against a uranium-oxide (U_3O_8) standard each day before readings were taken on the animals. Readings on the standard agreed within 1 to 2 per cent., so that the repeated readings over the lesion and bone, mentioned previously, were primarily a check on the accuracy of orienting the aperture of the lead plate over the lesion.

Since the number of counts obtained over the lesion or bone varied from 200 to 7,000 per minute, it was necessary that determinations of the counting efficiency of the tube be made over the range of rates encountered. The tube was, therefore, calibrated against a series of standards containing various amounts of U_3O_8. Since there is a possibility of error with the larger amounts of U_3O_8, due to "self absorption", the tube was also calibrated against a series of carefully measured amounts of Na_2HPO_4 containing P^{32}, prepared by dilution and evaporation to the dryness of a single original solution of the phosphate. The calibration curve thus constructed covered a counting range of from 30 to 8,000 counts per minute. The counting rate observed was directly proportional to the amount of radio-activity up to a rate of 1,200 counts per minute. Above this rate, corrections were needed, the maximum corrections used being 14 per cent.

An additional precaution may be mentioned. In experiments other than those described here, it was necessary to use counter tubes closed off at one end with a stopcock. These tubes showed no sign of leakage, and maintained uniform counting characteristics for several weeks. However, when they were used on animals anaesthetized with ether, they changed their characteristics and lost their plateaux within 10 minutes. This diffi-

culty disappeared when nembutal was used for anaesthesia. Apparently ether enters the counter through the stopcock grease.

The amount of radio-activity in the lesion and the comparable area of the normal contralateral bone was calculated as follows:

1. The background reading was subtracted from the reading over the bone or lesion, and this value was corrected for counter efficiency from the calibration curve of the counting tube.

2. The animals in any one group were not of uniform weight. Instead of adjusting the dose injected to the weight of each animal, it was assumed that all rats were of standard weight,—that is, 400 grams for adult and 50 grams for young rats. The adult rats received 8 times as much of the radio-active isotope as the young; this was, however, the same dose per gram of weight. To correct for the variations in weight within each group, the reading, corrected for background and counter efficiency, as described, was multiplied by the ratio of the actual weight of the animal to the standard for the group.

3. The number of counts in the injected dose was determined from a series of standards made of carefully measured amounts of different dilutions of the solution injected.

4. The corrected reading over the lesion was then divided by the number of counts in the injected dose, allowance, of course, being made for decay. This gives the radio activity in the lesion as percentage of the injected dose.

5. Instead of using as a basis for comparison the injected dose per animal, which was 8 times as great in the adult as in the young rats, the injected dose per gram rat, which was the same for both groups, was used. The values so obtained are the ones shown in the tables and graphs.

The relation between the per cent. injected dose and the per cent. injected dose per gram may be illustrated as follows:

R = corrected reading in counts per minute;
I = injected dose in counts per minute;
W = weight in grams of the animal (group standard);

$$\text{Per cent. injected dose} = \frac{R}{I} \times 100 = P_1;$$

$$\text{Per cent. injected dose per gram} = R \div \frac{I}{W} \times 100 = \frac{R}{I} \times 100 \times W = P_1 \times W = P_2.$$

In other words, the per cent. injected dose per gram rat is the per cent. injected dose multiplied by the standard weights for each group.

6. The values for the ratios L:N and EL:EN are obtained directly from the readings, corrected only for background and counter efficiency, since the other corrections apply to both numerator and denominator.

RESULTS

The data are tabulated in the following tables in which L is the reading over the lesion before exposure, N the reading over the normal tibia before exposure, and EL and EN are, respectively, the readings from the exposed lesion and the exposed normal bone.

The data presented in Table I are from animals which received 1 milligram or less of strontium chloride and sodium acid phosphate (tracer dose).

Table II shows the result of injections which exceed tracer doses. Because the specific activity,—that is, Sr^{89} per gram of strontium chloride—was low, these animals received 17.6 milligrams of strontium chloride. The lower percentage of retention in the bone is probably due to greater excretion when excessive amounts of strontium chloride were used. It is clear from comparison of columns EL in Tables I and II that the percentage of the injected dose per gram retained in the lesion after the excessive dose

TABLE I

COMPARISON OF THE UPTAKE OF RADIOPHOSPHORUS AND RADIOSTRONTIUM BY HEALING BONE IN RATS (EVANS'S STRAIN), ONE YEAR OLD, WEIGHING 260 TO 550 GRAMS

Post-operative Days	Radiophosphorus (P^{32})				Radiostrontium (Sr^{89})				$Sr^{89}:P^{32}$	
	L*	EL*	L:N*	EL:EN*	L*	EL*	L:N*	EL:EN*	EL*	EL:EN*
2	1.74	3.04	0.85	1.24	2.88	5.27	1.01	1.35		
	1.74	2.16	0.95	1.07	3.37	5.74	1.08	1.25		
	1.74	3.16	1.20	1.78	5.06	8.15	1.45	1.67		
	1.61	2.11	1.02	1.00	5.74	10.70	1.35	1.72		
					4.85	6.15	1.61	1.47		
	1.71	*2.62*	*1.01*	*1.27*	*4.38*	*7.20*	*1.30*	*1.49*	2.75	1.17
4	1.92	2.94	1.07	1.47	2.97	5.94	1.01	1.17		
	1.87	2.91	1.84	2.22	3.48	6.43	1.09	1.55		
	1.88	2.42	1.40	1.62	4.54	9.31	1.75	1.90		
	1.82	2.16	1.49	1.41	4.16	11.10	1.95	2.50		
	1.58	1.77	1.18	1.23						
	1.81	*2.44*	*1.38*	*1.59*	*3.79*	*8.22*	*1.45*	*1.78*	3.36	1.12
6	2.95	4.80	2.11	3.38	9.56	14.00	2.92	2.96		
	2.96	4.59	2.32	2.92	8.98	17.72	1.52	2.45		
	4.23	5.11	1.84	1.88	8.20	15.93	1.93	3.65		
	2.68	5.29	2.00	4.23	8.26	12.50	2.78	2.30		
	2.45	4.60	1.63	2.83	5.31	10.26	2.03	2.78		
	2.70	3.97	1.81	2.20	6.81	15.00	2.69	4.28		
	3.00	*4.73*	*1.99*	*2.91*	*7.85*	*14.24*	*2.31*	*3.07*	3.02	1.05
8	4.08	7.34	2.40	3.10	10.85	22.46	4.33	4.37		
	7.54	11.17	4.11	5.35	14.60	29.20	5.52	7.11		
	7.16	7.95	4.56	4.12	7.14	11.16	2.82	2.48		
	5.07	9.66	3.05	4.72						
	4.77	8.56	3.51	6.29						
	5.72	*8.94*	*3.53*	*4.72*	*10.87*	*20.94*	*4.22*	*4.65*	2.34	0.99
11	5.20	10.24	3.86	6.82	12.24	21.35	2.53	3.36		
	7.22	13.86	3.79	5.39	17.22	32.30	3.29	4.86		
	6.50	9.89	4.69	6.66	15.85	31.40	4.14	5.74		
	5.00	8.14	3.37	4.88						
	6.16	10.68	3.87	6.33						
	†5.34	7.99	2.58	3.50						
	5.90	*10.13*	*3.69*	*5.60*	*15.10*	*28.35*	*3.32*	*4.65*	2.80	0.83
13	7.24	11.75	4.28	5.79	24.73	41.60	6.32	6.75		
	6.02	10.23	4.16	5.98	21.90	30.26	6.50	5.35		
	4.98	8.89	3.94	5.20	17.58	31.80	3.54	5.00		
	8.24	11.37	4.61	4.86						
	5.69	10.07	4.88	7.55						
	5.84	8.79	4.00	5.54						
	6.34	*10.19*	*4.31*	*5.82*	*21.40*	*34.55*	*5.45*	*5.70*	3.39	0.98
15	5.10	7.98	3.24	4.88	20.10	50.50	9.26	11.23‡		
	12.32	18.10	5.68	7.28	14.20	27.70	3.14	4.11		
	8.32	15.27	6.31	7.77	21.50	35.30	3.67	5.09		
	5.55	8.60	3.38	3.81	15.03	29.20	5.26	8.82		
					15.95	32.30	5.93	6.94		
					9.66	23.45	4.97	7.24		
					16.48	36.38	6.13	8.94		
					12.51	26.10	6.94	7.88		
					14.13	30.60	6.11	7.47		
					16.09	23.27	6.41	7.43		
	7.82	*12.49*	*4.65*	*5.94*	*15.57*	*31.48*	*5.78*	*7.52*	2.52	1.27

TABLE I (continued)

Postoperative Days	Radiophosphorus (P^{32})				Radiostrontium (Sr^{89})				Sr^{89}:P^{32}	
	L*	EL*	L:N*	EL:EN*	L*	EL*	L:N*	EL:EN*	EL*	EL:EN*
18	4 42	8 86	2 15	3 46	12 87	22 40	4 98	5 45		
	5 42	6 72	3 06	4 19	11 42	18 33	4 66	4 76		
					12 82	23 33	2 82	4 00		
	4 92	*7 79*	*2 61*	*3 83*	*12 37*	*21 35*	*4 15*	*4 74*	2 74	1 24
21	2 79	3 40	1 92	2 31	10 45	20 20	3 00	3 99		
	4 31	6 72	2 90	3 68	9 80	14 57	1 92	2 13		
	4 35	6 64	2 26	2 81	11 83	21 50	3 58	5 08		
	3 82	*5 59*	*2 36*	*2 93*	*10 69*	*18 76*	*2 83*	*3 73*	3 36	1 2

* The values for L, N, EL, and EN used in all the tables and graphs are in percentage of the injected dose per gram rat.
† On inspection, lesion showed little sign of healing.
‡ Wound showed exceptionally large amount of callus.

The following calculations and their possible implication are presented merely as a further illustration of the usefulness of the technique

The lesion is roughly 0.2 by 0 5 centimeters and, assuming a depth of 2 0 millimeters, has a volume of 0 2 by 0 2 by 0.5 = 0 020 cubic centimeters. For a specific gravity of about 1, this will be about 20 cubic milligrams of tissue. At the peak (the thirteenth day), 34 55 per cent of the injected dose per gram rat was found in the lesion. This is 0.3455 by 10^3, or 345 per 100 milligrams, or about 17 times as much as would be expected, if the injected solution were distributed uniformly throughout the body and there were no excretion. If excretion is allowed for, the concentration in the lesion is even greater Compared with this, the concentration in the lesion on the second postoperative day is only one-fifth, or about 3 times the concentration of the injected dose, if uniformly distributed Since EL EN on the second day is about 1.5, the normal bone has a concentration of 3 54 1 5 or about 2.4 times the injected solution.

of strontium chloride was only one-third or one-half that observed after the smaller dose. Nevertheless, the ratios of the readings over lesion and normal bone through undisturbed skin (L:N) and over the exposed areas (EL:EN) are similar in both sets of animals.

In the rats 1 month old (Table III), the radiophosphorus was given in tracer doses of less than 1 milligram of sodium acid phosphate, but it was found necessary to administer 4.4 milligrams of strontium chloride, which is in excess of a tracer dose. The data in Tables II and III cannot be used, therefore, to determine the absolute amount of strontium taken up by the bone under physiological conditions. Thus the ratio of radiostrontium to radiophosphorus does not represent the relative amount of each element

TABLE II

COMPARISON OF THE UPTAKE OF RADIOPHOSPHORUS AND RADIOSTRONTIUM BY HEALING BONE IN RATS (SLONAKER'S STRAIN), WEIGHING 250 TO 350 GRAMS

Postoperative Days	Radiophosphorus (P^{32})*				Radiostrontium (Sr^{89})†				Sr^{89}:P^{32}	
	L	EL	L N	EL:EN	L	EL	L:N	EL:EN	EL	EL:EN
2	1 50	2 10	1 03	1 34	1 36	2 06	0 83	0 93	0 98	0 69
4	1 61	2 38	1 11	1 49	1 90	3 42	1 52	1 48	1 44	1 00
6	1 93	3 09	1 63	2 09	4 26	5 51	1 67	1 93	1 78	0 92
8	3 08	5 27	2 16	4 00	7 73	10 70	4 83	4 62	2 03	1 16
10	4 60	6 83	2 98	4 00	6 45	9 42	3 67	3 71	1 38	0 93
12	3 86	7 93	2 54	4 64	7 48	12 03	5 88	6 97	1 55	1 50
15	6 67	11 73	2 95	4 69	10 20	15 58	5 77	6 29	1 33	1 31
18	2 29	3 74	2 24	3 09	8 82	13 09	3 54	3 67	3 50	1 19
22	2 23	3 09	1 95	2 72						

* The values for postoperative days 2, 4 10 15 and 22 are means of three animals: and those for postoperative days 6, 8, 12, and 18 are means of
† All values are means of two animal
of 3 or 4 animals.

TABLE III

COMPARISON OF THE UPTAKE OF RADIOPHOSPHORUS AND RADIOSTRONTIUM BY HEALING BONE IN RATS (SLONAKER'S STRAIN), ONE MONTH OLD, WEIGHING 50 TO 70 GRAMS

Post-operative Days	Radiophosphorus (P^{32})				Radiostrontium (Sr^{89})				$Sr^{89}:P^{32}$	
	L	EL	L:N	EL:EN	L	EL	L:N	EL:EN	EL	EL:EN
2	1.52	3.86	0.41	0.91	2.24	3.76	0.82	0.90		
	3.31	2.87	1.32	0.80	2.07	2.80	0.61	0.77		
	1.83	2.64	0.80	1.16	2.24	3.77	0.60	0.90		
	1.50	3.04	0.55	0.95						
	2.00	3.36	0.90	0.83						
	2.03	*3.15*	*0.80*	*0.93*	*2.18*	*3.44*	*0.69*	*0.86*	1.09	0.93
4	2.01	5.05	1.19	1.21	2.80	3.57	1.33	1.20		
	3.39	5.56	1.07	1.54	2.89	4.44	1.35	1.48		
	4.07	5.94	1.24	2.10						
	2.58	3.98	1.32	1.19						
	2.79	4.06	1.38	1.46						
	2.97	*4.92*	*1.24*	*1.50*	*2.85*	*4.01*	*1.34*	*1.34*	0.82	0.90
6	4.14	6.52	1.30	1.75	1.97	4.96	1.77	1.93		
	3.72	8.83	1.04	1.82	2.99	4.99	1.13	1.41		
	3.88	6.21	1.81	1.69	4.32	5.60	1.22	1.60		
	2.72	5.60	1.24	1.39	4.48	6.16	1.12	1.48		
	2.69	3.46	1.84	1.81						
	2.17	3.33	1.09	1.31						
	3.22	*5.68*	*1.39*	*1.63*	*3.44*	*5.43*	*1.46*	*1.61*	0.96	0.99
8	2.94	6.62	1.44	2.11	4.56	6.27	1.59	1.95		
	4.68	5.81	1.93	2.06	4.44	8.33	2.95	2.59		
	5.05	5.87	2.08	1.79	7.13	8.51	1.78	1.94		
	3.18	5.91	1.09	1.55	6.87	8.20	1.86	2.00		
	3.92	5.55	1.15	1.48						
	3.12	4.48	1.48	2.23						
	3.44	5.29	1.43	1.83						
	4.20	5.83	1.79	1.82						
	3.60	5.96	1.55	1.84						
	3.79	*5.70*	*1.59*	*1.86*	*5.75*	*7.83*	*2.05*	*2.12*	1.36	1.14
10	2.47	5.14	1.78	1.91	8.44	12.50	1.67	2.20		
	3.36	5.79	1.49	1.42	5.22	8.91	1.91	2.25		
	2.46	3.53	2.50	1.60	7.05	9.80	1.77	2.23		
	6.10	0.30	1.59	1.82						
	5.87	8.07	1.24	1.35						
	4.33	6.68	1.80	2.24						
	4.19	5.31	1.69	1.75						
	3.50	4.37	1.48	1.74						
	4.04	*6.02*	*1.70*	*1.73*	*6.90*	*10.40*	*1.78*	*2.23*	1.73	1.31
12	3.31	4.30	1.46	1.39	5.72	7.61	1.39	1.58		
	4.02	5.71	1.42	1.61	6.60	9.24	1.97	2.08		
	3.10	6.35	1.42	1.52						
	4.72	7.63	1.54	1.79						
	3.79	*6.00*	*1.46*	*1.58*	*6.16*	*8.43*	*1.68*	*1.83*	1.41	1.16
14	4.51	6.95	1.36	1.95	5.99	7.05	1.94	1.48		
	3.23	5.92	1.12	1.58	6.54	7.11	2.00	1.41		
	1.79	3.99	1.12	1.30						
	3.18	*5.62*	*1.20*	*1.61*	*6.27*	*7.08*	*1.97*	*1.45*	1.26	0.90

that would be taken up under ideal tracer conditions. The change in this ratio as a function of the age of the wound, however, is indicative of changing conditions in the healing lesion.

In the young animals, the absolute rate of uptake (EL), as well as the relative uptake, is at a maximum on the eighth to tenth day after the lesion is made. In the older animals, the maximum is not reached until the fifteenth day. On visual inspection, the wounds in the young rats appeared to be healed by the tenth day, and could usually be located by the presence of a slightly raised white callus. In the old rats, the lesion was still not healed by the fifteenth day. It appeared as a fine brown line in a depression, with slightly raised callus on either side. The time it takes a wound to reach a maximum uptake of radiophosphorus or radiostrontium may, therefore, be used as a measure of the rate of healing. The values obtained from readings through undisturbed skin (L and N), and the ratios obtained from them (L:N), parallel those taken over the exposed lesion, thus making it possible to measure the rate of healing of a bone lesion without exposing it. Since the ratios L:N and EL:EN both increase by a factor of 4.5 to 5 in the course of the healing process (Table I), it should not be difficult to follow the effect of various agents on that process. Although the individual variations are rather large, marked deviations from the mean of the group usually can be accounted for. For example, the uptake of P^{32} at 11 days, shown by the ratio for EL:EN of 3.5 (Table I), was obtained from an animal whose wound was much retarded and appeared more like one in its sixth day; while the uptake of Sr^{89} at 15 days, shown by the ratio for EL:EN of 11.23 (Table I), was obtained from a wound with an excessive amount of callus.

Normal bone shows a higher percentage of uptake of radiophosphorus in young than in old animals, presumably because the young bone is growing. In the early stages of healing, there is little difference in the relative amount (EL:EN) of radiophosphorus taken up in lesions of the old and young rats; but in the later stages (from 8 to 15 days) there is about 3 times as much in the lesions of the old animals as in the young. This is simply an index of what may be observed by visual inspection,—that is, a greater quantity of osteoid tissue is formed in old as compared to young animals.

There is no apparent difference in the time at which uptake of radiostrontium by healing bone reaches a maximum, as compared to the uptake of radiophosphorus. It appears to be impossible by this method to detect a proliferation and calcification stage in the healing of bone. The percentage of radiophosphorus taken up in the lesion (EL), however, may be compared to the amount of radiostrontium similarly taken up. The ratio of radiostrontium to radiophosphorus may be calculated from the percentage uptake in the exposed lesion or from the amount in the lesion relative to normal bone (EL:EN). The values obtained by these procedures are listed in the last two columns in the tables. In Table I, the ratio of strontium to phosphorus in the exposed lesions varies from 2.3 to 3.4 with no obvious trend. This variability may be a reflection of the large range in weight of the animals used, which would not affect the ratio of EL to EN, but might be reflected in calculations in the percentage of uptake. It is probably also significant that these animals were not from an inbred strain. In Tables II and III, there is some indication of a trend to a maximum on the eighth to twelfth day. These animals were all from an inbred strain and their weights and ages were much more uniform.

If the relative uptake of radiostrontium and radiophosphorus is the same as for normal bone, the ratios of strontium to phosphorus obtained by the second method mentioned above,—that is, EL:EN strontium divided by EL:EN phosphorus, should give a constant value of 1. For the young rats (Table III), the ratio averages 0.94 for the first 6 days after operation and 1.13 from the eighth to the fourteenth day. Similarly, for old rats, the average ratio is 1.02 for the first 13 days, and 1.26 for the next 8 days (Table I). For the Slonaker strain of old rats (Table II), the mean ratios were 0.94 during the first period and 1.34 in the later stages of healing. Thus the calculations from these data show that relatively more radiophosphorus and less radiostrontium is taken up in the early stages of healing, as compared with the later stages. It should thus

be possible to distinguish between stages in the healing of bone in which proliferation predominates, as compared to stages in which calcification is predominant.

Where it is necessary to study the healing of deep-seated bone, the gamma-active radiostrontium Sr^{85} may be used by the same methods as those described for radiostrontium Sr^{89}.

SUMMARY

1. A method is described for making uniform lesions in the bone to permit a study of its healing.

2. A method of using radio-active tracers to study the healing of bone *in vivo* is described.

3. The uptake by healing bone of radiophosphorus and radiostrontium is determined at different stages in the healing process.

4. The uptake by healing bone of phosphorus and strontium is compared.

5. The effect of the age of the animals upon the uptake of phosphorus in the healing of bone is studied.

6. In young animals, the latent period for an increased uptake of phosphorus is shorter than in older animals (2 as compared with 4 days).

7. The maximum uptake of phosphorus and strontium occurs on the eighth to the tenth day in young rats, as compared with the maximum of 15 days reached in old rats. This parallels the gross healing of the old and young bones.

8. By comparing the ratio of uptake of strontium and phosphorus, it is seen that this ratio tends to increase later in the healing process; it may be possible to utilize this tendency to differentiate between the proliferating and the calcifying stages of bone-healing.

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THE INTERVERTEBRAL DISC: ITS MICROSCOPIC ANATOMY AND PATHOLOGY

PART I. ANATOMY, DEVELOPMENT, AND PHYSIOLOGY

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The clinical picture of backache has often been an enigma to the medical profession. Much excellent work has been done on the subject of backache, but there is much left to be discovered. Posterior protrusion of an intervertebral disc has only relatively recently been recognized as a clinical entity. As a factor in backache, its importance cannot be overstressed. A working knowledge of the anatomy and pathology of the intervertebral disc is especially important from this standpoint.

Most backache occurs in the region of the lumbosacral "joint". This region carries most of the strain of the spinal column, and, as has been stated by Goldthwait, half of the motion between the lower thoracic region and the sacrum takes place here. It is, therefore, logical that investigation of the intervertebral discs be centered in this region.

It is important to understand the evolutionary factors involved in the lumbosacral region. It is here that much in the way of "congenital defect" takes place, and individual variation is rather great. The evolution of this region has been fully summarized by Keith. His extensive work has brought to light the changes in structure and mechanics that have occurred as the species has evolved from the horizontal to the upright position.

TABLE I

AGE INCIDENCE OF SPECIMENS STUDIED

Age (*Years*)	Cases
0–10	5
11–20	6
21–30	8
31–40	9
41–50	11
51–60	22
61–70	16
71–80	11
Total	88

In order to shed some light on this complicated problem of backache, a microscopic study of the lumbosacral intervertebral disc has been carried out. Clinical symptoms or signs have not been used. Roentgenograms of the discs, with their adjacent vertebrae, have been taken, after removal at necropsy, in order to correlate the roentgenographic findings with the appearance of the same specimen through the microscope.

The first paper covers the method of study, the anatomy, the embryology, and the physiology of the intervertebral disc. Two subsequent papers will deal with (1) the changes to be expected within each age group—an attempt to establish a "normal" microscopic appearance—and (2) pathological changes in the intervertebral disc.

SOURCE OF MATERIAL AND METHOD OF STUDY

The material in this study was obtained during routine necropsy of eighty-five subjects. Three additional cases, taken at a somewhat later date, were also used to amplify

FIG. 1

Intervertebral disc of a man, aged fifty-four years. *A*: Cartilaginous plate. *B*: Annulus fibrosus. *C*: Nucleus pulposus. *D*: Bony rim. The arrows indicate the junction of the cartilaginous plate and the bony rim. *E*: Bony spur. (× 3)

the study of pathological discs. Thus the total number of cases studied was eighty-eight. Fifty-one subjects were male and thirty-seven were female. The youngest subject was aged ten months; the oldest, seventy-nine years.

Table I shows the distribution of cases by decades.

After the specimens were removed from the spinal column, they were fixed in formalin, and then a lateral roentgenogram was taken. After this, the specimens were sectioned mid-sagittally with the band saw, and a thin sagittal section in turn was cut from one of the halves. This section was prepared for microscopic study by decalcification [8], imbedding in paraffin, and sectioning with the microtome. The microscopic sections were stained by three methods: (1) hematoxylin and eosin, (2) van Gieson, and (3) De Galantha's method for mucin.[7]

The prepared sections were studied microscopically, but much additional information was obtained by projecting the slide on a screen, and studying the disc as a whole in its grosser aspects, at a magnification of twelve diameters. Each section was of course carefully compared with its corresponding roentgenogram.

THE ANATOMY OF THE INTERVERTEBRAL DISC

There are twenty-three intervertebral discs in the normal spinal column. They make up, roughly, a quarter the height of the vertebral column. They are thinnest in the thoracic region and thickest in the lumbar region. We are especially concerned with the fifth lumbar disc, but the structure of all the intervertebral discs is relatively the same.

A. *Adjacent Vertebrae*

The vertebrae adjacent to the discs, that is, cephalad and caudad, are composed of a cancellous type of bone, with rather specialized bony plates of denser, smooth bone, situated superiorly and inferiorly. These bony plates are, however, simply a reflection of

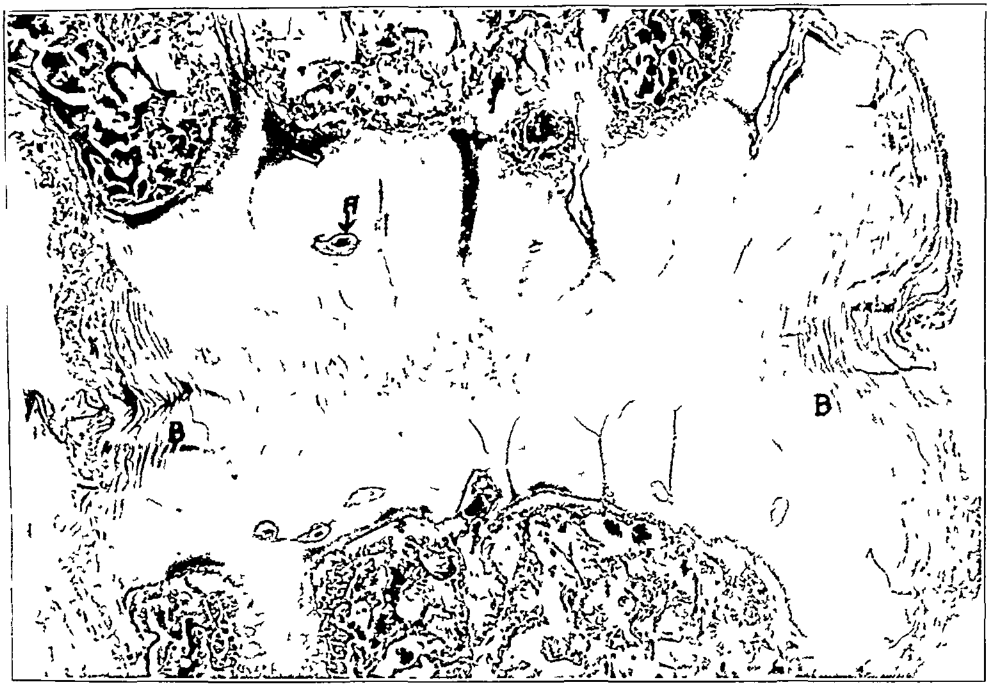

FIG. 2

Intervertebral disc of a girl, aged ten months. *A*: Vascular channel in the cartilaginous plate. *B*: Annulus fibrosus. (× 7)

the spongy bone of the body of the vertebra, for they are perforated by many small holes corresponding to the marrow cavities. Each end plate is divided into three zones:

1. Central zone, with small, numerous holes.
2. Peripheral zone, with larger, less numerous holes. These perforations in the central and peripheral zones are probably for nourishment of the adjacent discs, as they allow fluid to pass from the spongy bone into the disc.
3. Epiphyseal ring, surrounding the outside of the end plate. It is raised and is composed of dense bone. This is the *Randleiste* of Schmorl; it was first described by Fick. Externally it overlaps the outer surface of the vertebral body, and internally it slopes to meet the peripheral zone of the bony plate.

B. *Ligaments*

The ligaments of the spinal column with which we are concerned are the anterior longitudinal and posterior longitudinal ligaments. They extend anteriorly and posteriorly on either side of the spinal column from the axis to the sacrum, and are intimately blended with the underlying intervertebral discs

C. *Gross Anatomy of the Disc*

The intervertebral disc is like a cushion between the two adjacent vertebral bodies. It is composed of three rather distinct parts (Fig. 1):

1. *Cartilaginous Plate*: This structure of hyaline cartilage covers the bone of the vertebra, and acts as a limiting plate caudad and cephalad, with the fibrous disc proper in between.
2. *Annulus Fibrosus* (*Lamellosus*). This arises from the cartilaginous plates, surrounds the nucleus pulposus, and inserts into the anterior and posterior longitudinal ligaments and into the bone of the vertebrae It gives the size and shape to the disc, and is the seat of most of its strength and tenacity [2]

3. *Nucleus Pulposus:* This is the semigelatinous center of the disc, which is encapsulated by the annulus. It is a peculiarly active or dynamic portion of the disc, by reason of its turgescence.

D. *Blood and Nerve Supply to the Disc*

Übermuth, in 1929, and Böhmig, in 1930, expressed the belief that, up to the age of eight years, there are small blood vessels supplying blood to the disc by way of the cartilaginous plate. Übermuth further stated that these vessels begin to become scarred at the age of eight months, and scarring is complete at twenty to thirty years. These nutritive channels have also been described by Smith. The results of the present study tend to concur with these findings. Vascular channels with blood cells in their lumina are seen in the first three decades, but not as a rule following that time (Fig. 2).

Roofe, in 1940, found nerve endings in large amounts in the posterior portion of the annulus fibrosus and in the posterior longitudinal ligament. No specialized end organs were found in the authors' studies, but the type of terminal end organs indicated that they were probably pain fibers. No special nerve staining was done in our study. No fibers or nerve endings were observed with the routine stains.

E. *Microscopic Anatomy*

1. *Cartilaginous Plate*: The cartilaginous plates are composed of ordinary hyaline cartilage. They lie between the bone of the vertebrae and the fibrous components of the disc. The cartilage is found over the perforated bony end plate, but not over the compact peripheral zone or epiphysis. It is rather loosely cemented to the underlying bone by a very thin layer of calcium[10], which is absent at points corresponding to the perforations of the bony plate. The hyaline cartilage cells are arranged somewhat horizontally. The fibrocartilage of the annulus fibrosus takes its origin from the cartilaginous plates, as will be described later.

2. *Annulus Fibrosus* (*Lamellosus*): This structure is the "limiting membrane" for the nucleus pulposus. It is not entirely distinct from the nucleus, as the two tend to blend together. They are, none the less, separate structures. The annulus is the major part of the disc. It is composed of fibrous and fibrocartilaginous lamellae in an intricate arrangement. The fibers are of three groups: (1) those that "stream off" of the inner surface of the cartilaginous plates, where there is a gradual transition from hyaline cartilage to fibrocartilage; (2) those that pass anteriorly and posteriorly to insert into the longitudinal spinal ligaments, and (3) those fibers that pass over the edge of the vertebral body and sink into the bone of the vertebrae like Sharpey's fibers. The annulus is thought to be much stronger anteriorly, where the attachment to the longitudinal ligament is very strong, than posteriorly, where the attachment to the longitudinal ligament is much looser. The posterior ligament is also weaker than the anterior ligament. These facts may partially explain the much higher frequency of posterior than anterior protrusions of the disc.

The fibers of the annulus pass from the nucleus pulposus to the cartilaginous plate at right angles to the plate, but change their course and insert into the plate obliquely. Anteriorly and posteriorly the fibers are richly arranged in lamellae, and pass obliquely from the plate to the periphery in spherical fashion, turning up at the end to curve back to the opposite plate. Toward the periphery of the cartilaginous plate, the fibers pass out laterally from the end of the plate and divide into three groups. One group goes upward to the opposite plate, one blends into the fibers of the longitudinal ligament, and the third group, according to Beadle, "forms a small but pathologically very important system". It passes away from the disc, streams over the edge of the epiphyseal ring, and inserts into the bone of the vertebra, just as do the Sharpey fibers of the longitudinal ligaments. This is an important point, in Beadle's opinion, for it illustrates that the attachment of the disc

to the longitudinal ligaments, cartilage, and bone is stronger than is the attachment of the epiphyseal ring to the bone underlying it.

3. *Nucleus Pulposus*: When the disc is cut across horizontally, the tissue of the nucleus swells out as a white, glistening body, showing that the nucleus is normally under tension. The line of demarcation between the nucleus pulposus and the annulus is rather distinct in young subjects, becoming less so in adults. The nucleus usually occupies the region at the junction of the middle and posterior thirds of the disc.[5] It is formed of loose, wavy, fibrous strands in a liquid-saturated reticulum, which is gelatinous and mucoid. Notochordal remnants are said to be present at birth, and physaliferous cells of Virchow have been identified by some. These notochordal cells gradually diminish in number, and the nucleus becomes denser and more fibrous. In the adult disc, the nucleus pulposus contains cartilage cells and fibroblasts in a semigelatinous matrix. The fluid content of the nucleus diminishes from 88 per cent. in a full-term foetus to 66 per cent. in a seventy-seven-year-old subject, according to Püschel.

Various authors have described a central cavity in the nucleus, and some have compared it to a rudimentary joint cavity. There is no endothelial lining to these cavities, but villous-like processes can be seen to project into them. Others [4,23] have expressed the belief that these cavities are simply evidence of nuclear desiccation.

Whether there is true mucus in the nucleus pulposus is a somewhat controversial point. While this study reveals a distinctly mucoid reaction to hematoxylin and eosin stain, De Galantha's mucin stain does not show the presence of true mucus in any of the specimens. Deucher and Love were able, however, using mucicarmine stain, to get positive reactions for mucus in protruded discs removed during operation.

THE EMBRYOLOGY AND DEVELOPMENT OF THE INTERVERTEBRAL DISC

For proper interpretation of findings in the intervertebral disc and adjacent vertebrae, one must know something of the development of these structures. Excellent diagrammatic representations may be found in the work of Bradford and Spurling. The vertebrae, cartilaginous plate, and annulus fibrosus are derived from mesoderm. The nucleus pulposus is derived from endoderm, being in part a remnant of the notochord. Neither the primitive vertebrae nor the provertebrae correspond to the adult vertebrae. Each provertebra divides horizontally, and the caudad half attaches to the cephalad half of the adjacent provertebra. These halves unite to form the final rudimentary vertebra. The provertebra is marked off by the intersegmental artery, which is usually clearly seen in the spinal columns of young persons.

The intervertebral discs themselves apparently differentiate (or remain undifferentiated from the surrounding differentiating cells). As development proceeds, water leaves the cells, except in the region of the future intervertebral discs.[4] It has been postulated by Bardeen and Williams that this retention of water is due to the lack of nourishment to the region of the disc, as this region lies farthest from the intersegmental artery.

The notochord becomes extruded into the intervertebral regions as its canal gradually closes. At the end of the tenth embryonic week the cells of the vertebral bodies have become cartilaginous in type, and the cells of the notochord lie entirely within the disc, and can then be called nucleus pulposus. These cells undergo mucoid degeneration. They remain as notochordal-type cells until after birth, when they gradually disappear. The hypothesis of Dursy and Virchow, that the chief source of the nucleus pulposus was degeneration of the annulus fibrosus, has been disproved. There is no question that the primitive notochord is the anlage of the nucleus pulposus. Keyes and Compere emphasized the rather sharp line of demarcation, especially in the spinal columns of young persons, between the annulus fibrosus and the nucleus pulposus, which, they stated, is caused by a ring of fibroblastic tissue in the embryo. The persistence of notochordal cells up to the time of birth is also evidence of the origin of the nucleus.

Ossification of the vertebral bodies has been described extensively by Schmorl, and most of the following is obtained from his work. Formation of bone can be observed as early as the tenth embryonic week. Separate ossification centers appear for the bodies and for each half of the arch, at this time. At the time of birth, clefts or grooves appear in a radial fashion on the superior and inferior margins of the vertebral bodies. These increase in size for the first eight to ten years, then gradually smooth out until the twenty-first to twenty-fifth years. Strongly attached to the other elements of the intervertebral disc is the cartilaginous plate. It extends to the margins of the vertebral body, where it is intimately fused with the bony clefts and ridges. On the surface of the cartilaginous plate next to the bone, one finds the longitudinal growth of the vertebral bodies taking place. The columnar grouping of the cartilage cells, as in the long bones, can be readily seen.

The peripheral bony ring, or epiphysis, develops as follows: A small, triangular ring of cartilage surrounds the superior and inferior brims of each vertebral body. In this ring develop small foci of calcium, among girls at the age of six to eight years, among boys at the age of seven to nine years. These foci then ossify. Gradually they enlarge and fuse to form a ring,—the peripheral or marginal bony ring, or *Randleiste*. This ring is complete at the age of twelve years. At the age of fourteen or fifteen years, the peripheral bony ring gradually fuses with the vertebral body. This fusion is complete at twenty-one to twenty-five years. Fusion is slowest in the lumbar region.

Several authors [15,16] have described this ring as incomplete, because it is horseshoe-shaped and absent posteriorly. Others [10,21] have maintained that it is complete on all sides of the vertebra. While it is generally less broad posteriorly than anteriorly, it does exist as a complete ring. Any vertebra that has been freed of all soft tissue shows this ring posteriorly. Examination of eighty-eight microscopic specimens in this study has confirmed its presence posteriorly. The cartilaginous plate always ends before it reaches the posterior edge of the vertebra, abutting against a definite rim of bone (Fig. 1).

The inference made by Schmorl and Beadle is that the epiphyseal ring is a separate entity from the cartilaginous plate and serves a different function. Mau, Keyes and Compere, and Haas disagreed with this idea, believing that the two are intimately connected and serve the same function. At the end of longitudinal growth, the epiphyseal ring fuses to the vertebra, and the cartilaginous plate continues its function as part of the disc, its peripheral ends abutting on the bony rim of the epiphysis. Beadle, however, definitely stated that the epiphyseal ring is not concerned with growth. He maintained that there is no evidence of endochondral growth at the epiphysis, as there is at the base of the cartilaginous plate. He stated that the epiphysis simply grows within itself until it occupies the cartilaginous ring, then fuses to the underlying bone. Schmorl and Beadle expressed the belief that the epiphyseal ring is important only in that it serves to anchor the fibers of the annulus fibrosus firmly. They disagreed with Mau and others who claimed that wedging of the thoracic portion of the spinal column in juvenile "epiphysitis" is due to lack of growth in the epiphyseal ring. Instead, they expressed the belief that the wedging is due to herniations of the nucleus pulposus into the spongy bone of the adjacent vertebrae with resultant thinning of the disc and direct contact and compression of the anterior margins of the vertebrae. This controversial subject remains unsettled and our study does not shed any light on it one way or the other.

THE PHYSIOLOGY OF THE INTERVERTEBRAL DISC

The intervertebral disc is not a passive, vestigial remnant. It is an active, living structure, constantly functioning. The intervertebral discs serve, first, as articulations (amphiarthrosis) between the vertebrae. Without these discs the spinal column would be rigid, and could not bend to meet the delicate needs of the body. Some have called the disc a diarthrodial joint, even stating that it possesses a rudimentary joint space.[23,24] At any rate, it does serve to connect and articulate the adjacent vertebrae.

In addition to its function of articulation, the intervertebral disc acts as a shock

absorber or cushion. It transmits, modifies, and evenly distributes the force of strain. Beadle stated that the disc "is a unit whose function is to control the continual and infinitely various cross currents of tension, torsion, pressure, and mechanical shock, which interplay with one another as injurious agencies during every moment of life".

Dividing the intervertebral disc into its component parts, one sees that each of the three main structures is highly important in itself, but is dependent also on the others. The cartilaginous plate acts as a barrier between the active pressure of the nucleus pulposus and the adjacent vertebral body. Only if the cartilaginous plate is intact, will the disc act normally. If the cartilaginous plate is perforated or torn, the nucleus pulposus is allowed to flow into the adjacent vertebra, and it can no longer act as a hydrodynamic ball bearing.[6]

The nucleus pulposus is under tension in persons up to the older age groups. This tension can be simply illustrated by cutting a section through the disc and noting the bulging forth of the nucleus. The semifluid nucleus pulposus is held in restraint by the surrounding annulus fibrosus. Any movement of the spinal column is accompanied by a shift of forces in each nucleus pulposus. Flexion of the spinal column causes an anterior *compression of the nucleus, with a tendency for the nucleus pulposus to be displaced posteriorly.* This is the phenomenon of "nuclear retropulsion" as described by Galland. Extension of the spinal column does the opposite. A lateral shift, as in scoliosis, in turn shifts the nucleus in the opposite direction. If nuclear material is lost, as in the desiccation of old age or rupture of the nucleus pulposus, the disc no longer serves to transmit the forces of strain, and the shock is borne solely by the vertebrae, their ligaments, or their facets.

The third component of the intervertebral disc—the annulus fibrosus—is the "limiting membrane" surrounding the nucleus and serving as its capsule. The fibrocartilage of which it is composed is woven together in a complex system, with the fibers running in various directions and anchoring at strategic points, all designed to give maximal function and to accommodate for every conceivable change of force. Schmorl stressed this ability of the annulus fibrosus to accommodate itself to its surroundings. When the strength of the annulus is lost through degeneration or injury, the nucleus ruptures, usually posteriorly, presses on nerve roots, and causes pain.

The intervertebral disc can be compared to a thick rubber ball, filled with fluid, and partially compressed between two rigid discs. When the position of the discs, and the distribution of force on them change, the position of the ball changes and its shape also changes accordingly. Puncture of the ball, with escape of fluid, results in loss of tension, and the two discs are allowed to come closer together than before.

The intervertebral discs act somewhat differently in the various regions of the spinal column. There is little doubt, however, that the lower lumbar discs receive more shock and strain than any other. For this reason, this study is concerned with the fifth lumbar disc. Not only are the usual forces more active here, but there is the added shearing force as the fifth lumbar vertebra tends constantly to ride forward on the first sacral. This disc, of all the discs, is the most used and the most abused. One finds evidence here of wear and tear at an earlier age, and to a greater degree, than in any other intervertebral disc.

CONCLUSION

As a result of study of the anatomy, embryology, and physiology of the intervertebral disc, the following conclusions are drawn:

1. Vascular channels in the cartilaginous plate are normally present only in the first three decades of life.
2. There is no central "joint cavity" in the intervertebral disc.
3. No mucus was demonstrated in the intervertebral disc by De Galantha's stain.
4. The peripheral bony ring, epiphysis, or *Randleiste* is present as a complete ring, and is not absent posteriorly.

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SACRAL FRACTURES AND INJURIES TO THE CAUDA EQUINA

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The association of cauda equina injuries with crush fractures of the sacrum must have been noted by many an observer, but, as far as the literature was searched, no record of any analysis of such cases could be found. It is possible that intending authors were daunted by such words as these, uttered by Kinnier Wilson: ". . . the cauda equina is too complex a structure for simplicity of syndrome, but the form all variants assume is, and must be, radicular; if otherwise, the syndrome is no longer 'pure'". The recent concentration of interest on herniation of intervertebral discs has shed new light on the problems of the lumbosacral plexus, and, at the same time, has made facts culled from the observation of injuries to the upper sacral nerve roots of greater relative interest.

Prolapse of the fifth lumbar intervertebral disc produces pressure on the first sacral nerve root primarily, but, if the prolapse is more medial or more extensive, some pressure on the second sacral nerve root may occur. The muscular and cutaneous phenomena associated with this are not sharply defined, owing to the overlap provided by pathways through other roots, but nevertheless produce a readily recognizable syndrome; in the case of the first sacral nerve root, this is characterized by weakness of the plantar flexors of the foot. This syndrome is closely parallel to that which is due to involvement of the first and second sacral nerve roots from fracture of that part of the sacrum in juxtaposition with the sacro-iliac joint. Further observation of this latter syndrome should extend our knowledge of the effects of pressure on the second sacral nerve root.

ANATOMY

The long auricula-shaped facet of the sacro-iliac articulation extends from the level of the upper margin of the first sacral foramen to the upper margin of the third. The first and second anterior and posterior sacral foramina thus weaken considerably that part of the bone connecting the lateral mass of the sacrum with the body of the bone, and provide the most readily broken link in the solid connections between the ilium and the vertebral column. From this weak spot, fractures of the sacrum caused by indirect violence are prone to start and spread; and it follows that any fracture of the sacrum caused by violence transmitted through the sacro-iliac joints affects this area to a greater degree than elsewhere. This tends to involve predominantly the first and second sacral nerve roots, while the lumbosacral trunk above and the third sacral nerve root below may be involved to a lesser degree.

MODE OF SACRAL FRACTURE

Fracture of the sacrum is most common in association with fracture of the innominate bone, a sufficient clue to its most common method of production. The bone is strongly resistant to compression; and, in the intact pelvis, excluding direct violence, it can be acted upon only by compression force. The more common sacral and pelvic injuries are secondary to violence applied to one leg or to one side of the body. Consideration of the mechanics of the bone, as well as of the common type of violence, thus suggests that the sacrum is broken by tension and shear, forces to which all bones offer least resistance. The idea that this violence is transmitted through the innominate bone is in conformity with the ideas recently expressed by Taylor on the violence causing dislocations of the innominate bone. Fracture through the weak area of the bone may occur in three ways, or four, if pure compression is given its unimportant place.

1. *By rotation:* The injury is severe with separation of the pubic symphysis, c fracture of the ischiopubic rami. The force is one of hyperextension, acting on the lowe extremity, and rotates the affected innominate bone around the horizontal axis of th sacro-iliac joint, so that the pubis is depressed. If the sacro-iliac joints do not yield (an to rotation they offer their greatest resistance), fracture through the first and secon sacral foramina occurs. The fact that this rotation takes place is frequently shown b elevation of the posterior superior iliac spine, without elevation of the innominate bon concerned. Rotation of the innominate bone in the opposite direction is less common and is indicated by elevation of one side of the pubic symphysis.

2. *By leverage:* Once the pelvic ring has been broken anteriorly, its two halves ma be widely separated. The force responsible may be considerable, as in "run-over" acci dents, or when transmitted through the abducted limb. Once the sacro-iliac joint has bee opened to its maximum, there is a tendency for fracture to occur through the buttresses o bone between the first and second sacral foramina, as a fully opened hinge tends to tea out by the screws. Less commonly, this action is reversed, and the pubic symphysis is made to overlap by compression.

3. *By shear:* One half of the pelvis may be driven almost directly backward by impact against the knee, when the patient is in the sitting position. More commonly this produces posterior dislocation of the hip; but, if the hip is slightly abducted, one half of the pelvis may be pushed up and back. Under these conditions, the lateral mass of the sacrum is submitted to a shearing stress, under which it is most likely to fracture.

As a general rule, no accurate analysis of these forces is possible in the individual case, in which they are combined in a greater or lesser proportion. The high incidence of sacral fracture in association with fractures of the pelvic ring is thus accounted for, although statistics of this vary widely; thus Wakeley gives 4 per cent. as the figure, while Furey gives 74 per cent. The frequency with which sacral fractures will be seen depends chiefly upon the quality of the roentgenogram and the industry with which they are sought, for postmortem examination shows small chip fractures at the margin of the sacro-iliac joint in almost every case of fracture of the pelvis. These are frequently invisible in the roentgenogram, because of the density of superimposed bone shadows. What we are interested in is the percentage of fractures of the sacrum visible in roentgenograms of reasonable quality, and the author's experience (Table I) confirms that of Mendelmann in giving a figure of 45 per cent. as approximately correct.

ROENTGENOGRAPHIC EXAMINATION

Satisfactory definition of the sacrum does not occur in the average roentgenogram taken for fracture of the pelvis, owing to the curvature and obliquity of the bone. As these two factors cannot be entirely overcome, a foreshortened view is always seen, in which the first and second anterior sacral foramina are very close to one another. The thin compact bone above each foramen is tilted edge on, and thus shows up in the roentgenogram as a fine line arching above each foramen. In many roentgenograms, this line above the second foramen appears as the continuation of the brim of the pelvis (Fig. 1, *G*). Above this is the curved line over the first sacral foramen, merging with the shadow of the lip of the first sacral body; while below, the third and fourth sacral foramina are more distinct. The posterior sacral foramina are obscured, and are recognizable only as an area of decreased density on either side of the mid-line. The weakest area of the sacrum is recognizable as running from the notch between the articular process for the fifth lumbar vertebra and the lateral mass of the sacrum above (Fig. 1, *C*), through the first and second foramina to emerge below at the edge of the sacrum, usually through the third sacral foramen.

In most views of the sacrum, two promontories are visible on the shadow of its lateral edge. The first represents the junction of the sloping upper surface of the bone with the most anterior portion of the auricular facet, and so lies just below the upper level of the

TABLE I

CLASSIFICATION OF FORTY-FOUR FRACTURES OF THE PELVIC RING *

Posterior Disruption	Anterior Disruption			
	Fractures of the Ischiopubic Rami on one side	Fractures of the Ischiopubic Rami on both sides	Separation of the Pubic Symphysis	Totals
No posterior lesions seen	6	4		10
Sacro-iliac dislocation				
Unilateral	2	1 (with sacral fracture)	2	5
Bilateral		1	2	3
Fracture of the ilium lateral to the sacro-iliac joint	2 (1 with sacral fracture)	1		3
Fracture of the ilium running into the sacro-iliac joint	3 (1 with sacral fracture)	4 (2 with sacral fracture)		7
Central dislocation of the femur	1			1
Fracture of the sacrum only	5	7	1	13
Fracture of the sacrum on one side, and of the ilium running into the sacro-iliac joint on the other		2		2
Totals	19	20	5	44

* This table shows the high incidence of sacral fractures associated with other fractures of the pelvis,—twenty sacral fractures, or 45 per cent.

The etiological classification of sacral fractures is as follows:

1. *By Direct Injury*
   a. Complex comminuted fractures from missiles;
   b. Transverse fractures below the level of the sacro-iliac joint;
   c. Compression fractures of the posterior arch.
2. *By Indirect Injury*
   As illustrated by the twenty cases of sacral fracture listed in Table I and classified in Table II.

TABLE II

ANALYSIS OF SACRAL FRACTURES

Type of Fracture	Main Fracture	Associated Fractures *
a. Juxta-iliac marginal fractures	5	6
b. Fractures through the first and second sacral foramina, with upward displacement of the lateral sacral mass	5	
c. Compressed and comminuted fractures of the same region, with loss of sacral pattern	4	
d. Fissure fractures separating the lateral mass through the first, second, third, and fourth sacral foramina, with little or no displacement	6	
e. Ligament-traction fractures at the attachment of the sacrotuberous ligament		3
f. Transverse fractures at the level of the third sacral foramina (caused possibly by direct violence, or possibly by ligament traction)		2
Totals	20	11

* These were small fractures of the sacrum associated with the twenty main fractures; but, as they occurred in the same cases, they cannot be added to the twenty fractures in individual cases.

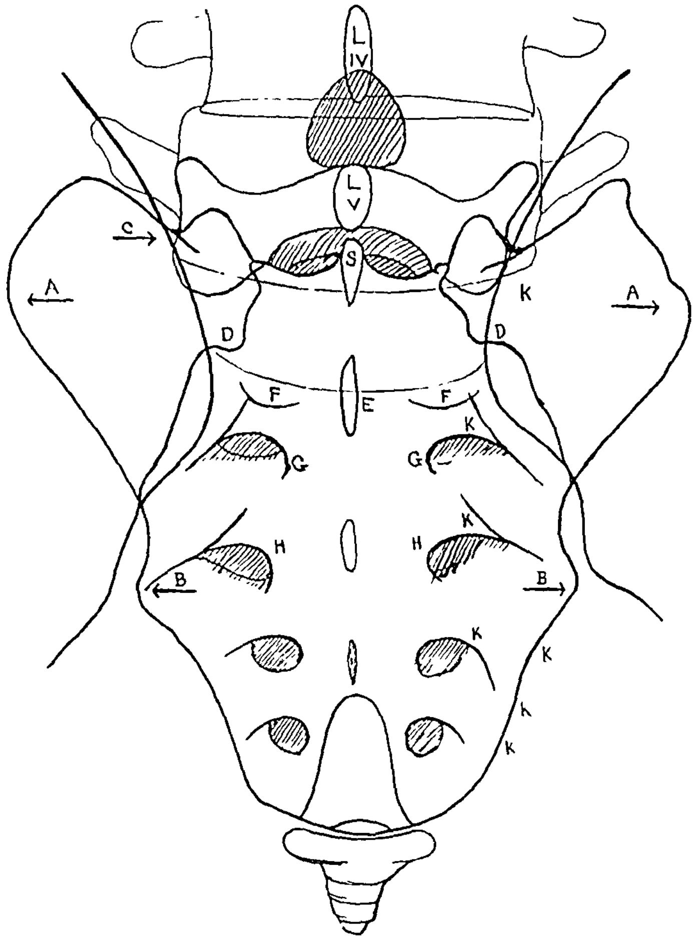


FIG. 1

FIG. 1

Diagram of the shadows cast by an average anteroposterior roentgenogram of the sacrum.

A-A: Line of the upper lateral sacral promontories.
B-B: Line of the lower sacral promontories.
C: Notch between the lateral mass and the articular facets for the fifth lumbar vertebra.
D: Notch representing the first posterior sacral foramen.
E: Shadow of sacral promontory.
F: First anterior sacral foramina.
G: Second anterior sacral foramina.
H: Third anterior sacral foramina.
K-K: Sites where fractures are common and readily found.

sacro-iliac joint, and the second and lesser promontory, which is missing in some views, lies opposite the brim of the pelvis and represents the lower border of the sacro-iliac joint. These points serve as convenient landmarks in true anteroposterior views of the bone, for comparative measurement with the opposite half (Fig. 1, *A-A* and *B-B*). In many crush fractures, these promontories will be found nearer to the mid-line than are those of the unaffected side. When this is of significance, it is usually apparent to the naked eye; minor degrees of change are easily produced by rotation of the pelvis and have to be discounted. As has been pointed out,[1] the value of the obstetric view of the pelvis in the determination of the displacement following pelvic fractures must not be forgotten. The usual change is an alteration in the outline of the brim of the pelvis, showing itself as an increased angulation through the line of the anterior sacral foramina, caused by the forward displacement or impaction of the lateral mass of the sacrum on the main mass of the bone (Fig. 2).

The recognition of sacral fracture is most readily accomplished by inspecting the continuity and regularity of the arches above the anterior sacral foramina, and comparing them with the opposite side. The inspection of the lumbosacral notch above (Fig. 1, *C*) may also provide information; the eye should then travel to the free border of the sacrum lower down. Fractures frequently come to view here, in the vicinity of the third sacral foramen. A linear fracture of the ligament-traction type may be apparent at the edge of the bone, corresponding to the attachment of the sacrotuberous ligament, and, if so, provides additional evidence of the movement of one half of the pelvis. This fracture was apparent from the beginning in one of the five cases reported here, but in another it became apparent only after a period of seven weeks had elapsed (Fig. 6-B). During this time, new-bone formation at the base of the detached ligament made the separation obvious, and substantially duplicated the picture seen in the first case (See Table II).

NEUROLOGICAL FEATURES

The syndrome arising from pressure on the first and second sacral nerve roots shares the vagueness of similar syndromes elsewhere, and yet forms a combination of sensory and motor changes which is readily recognizable. That such would be the case can be deduced from a consideration of the distribution of the nerve fibers in the plexus, and the fact that the damage in most cases is incomplete. The anterior sacral foramina are at least twice

the diameter of the issuing nerve roots, which would seem to make bone pressure unlikely, unless the displacement is considerable. Injury may, however, be produced by stretching, by the pressure of small fragments of bone, by surrounding hemorrhage, and probably by the contraction of fibrous tissue and callus. The onset of symptoms may thus be delayed, and few signs may be elicited at the time of the first examination, while more marked features may appear in the recovery period. Two of the reported cases show this feature (Cases 4 and 5).

The most characteristic feature of the syndrome is the distribution of the muscle paresis, which is caused by pressure or division of the first or second sacral nerves. If either or both are completely divided, obviously a rare phenomenon, the following muscles would be affected, according to various authors: [2]

Muscles Affected	Authority
Pyriformis *	Dejerine, Gray, Grinker, Monrad-Krohn
Gastrocnemius *	Dejerine, Gray, Grinker, Monrad-Krohn, Purves-Stewart, and Wechsler
Soleus *	Dejerine, Gray, Grinker, Monrad-Krohn, Purves-Stewart, and Wechsler
Glutei,—maximus, medius, and minimus †	Dejerine, Gray, Grinker, Monrad-Krohn, Purves-Stewart, and Wechsler
Semimembranosus	Dejerine, Gray, Grinker, Monrad-Krohn, Purves-Stewart, and Wechsler
Biceps femoris	Dejerine, Gray, Grinker, Monrad-Krohn, Purves-Stewart, and Wechsler
Flexor digitorum longus	Dejerine, Gray, Grinker, Monrad-Krohn, and Purves-Stewart
Tibialis posterior	Dejerine, Gray, Grinker, Monrad-Krohn, and Purves-Stewart
Intrinsic muscles of the foot *	Spalteholz and Berry
Plantaris *	Spalteholz and Berry

* Almost completely paralyzed.
† Grinker, Monrad-Krohn, and Wechsler believe that the glutei are not affected if only the second sacral is involved.

The peroneal and anterior tibial compartments are very slightly affected. Broadly speaking, we thus expect to find marked weakness of plantar flexion at the ankle, with loss of the ankle jerk, and loss of power in the hamstrings and in the glutei. Paresis of the three posterior groups of muscles of the lower extremity (calf, hamstrings, and buttock) thus characterizes the lesion; in addition, the severity of the paresis is selective, the calf being more markedly paralyzed than any other group. The segments which supply the biceps femoris seem to vary in the individual, but are most commonly given as the fifth lumbar, the first, second, and third sacral. Our observations would suggest that the first and second sacral are chiefly concerned; as, in two reported cases, the muscle was almost completely paralyzed, and in only one of these was damage to the fifth lumbar and third sacral roots likely. Marked paralysis of the biceps femoris was noted in all cases, and is probably a distinctive mark of the syndrome.

The ankle jerk will be lost, if there is serious damage to the first sacral nerve root; and its loss is a common feature of the syndrome. In less severe injuries, the reflex is diminished. The calf muscles and the hamstrings are always tender to the touch, and fibrillation may be seen.

SENSORY CHANGES

The sensory changes found occurred within the areas of the dermatomes assigned to the first and second sacral nerves. Although there is still no definite agreement among authorities as to the limits of the dermatomes, their locations have been roughly determined.[7] These are to be compared with the affected areas in Cases 3 and 4. Broadly speaking, alterations in sensation, paraesthesia, and referred pain are to be expected on the

outside of the calf and the lateral half of the foot. The changes we have noted are the same as those of nerve compression from any other cause. Thus immediate severe pain referred to the back of the leg and outer side of the foot was found. The patient complained of numbness and tingling in the area; and clinical examination demonstrated loss of sensation to light touch and disturbed sensation to pinprick. In view of the sensory overlap and the fact that lesions are most often incomplete, areas of complete loss of sensation are unlikely, except in very severe lesions. This incompleteness is frequently shown by the appearance of hyperaesthesia, either occurring in an isolated area (Case 4) or surrounding an area of otherwise altered sensation (Case 3). The sensory findings thus share the same qualities as those from the pressure of a herniated nucleus pulposus, but tend to affect the two roots—first and second sacral—together, in contrast to the single root involved in a disc lesion. Pain, however, is in marked contrast. While there is usually pain at the infliction of the injury, it rapidly subsides; and the patient is free from pain of a "nerve" type, although he may have aching as a result of the injury. It would appear that this is due to the fact that, in a herniated nucleus pulposus, the pain arises from tension on the nerve, which is intact. In the syndrome of the sacral fracture, the nerve is apparently completely or partly divided, and, after the infliction of the injury, is painless.

Fig. 2

Obstetrical view of the pelvis, showing the characteristic forward displacement of the lateral mass of the sacrum; the fracture obviously runs through the sacral foramina. Arrows indicate secondary fracture of the lateral mass.

Unless the remaining fibers are stretched or stimulated by some other method, there is no complaint of pain. A positive Lasègue sign in the early stages is often of doubtful significance, because of the extensive local damage, but it may become suggestively positive as the patient recovers. The nerves of the bladder and bowel issue below the second sacral nerve root, and, since the sacral fracture is unilateral, disturbance is not to be expected. A temporary upset of bladder and bowel function is, however, not uncommon. In the case of the bladder, it may arise from bruising in the neighborhood of the trigone or of the urethra. A ruptured urethra may be associated with the condition. Similarly, the rectum may be disturbed from hemorrhage into the pelvirectal fascia or the root of the sigmoid mesocolon, which may result in faecal impaction, while the immediate complete recumbency and lack of activity encourage constipation. Vasomotor and trophic changes are not found.

TREATMENT

The sacrum can be influenced only through that half of the pelvis attached to the fractured portion. Every endeavor must be made to reduce the pelvis satisfactorily by the use of the appropriate method. A sling, counterbalancing the patient's weight, together with traction on the lower end of the femur, will generally be found the most efficacious. Once the pelvic displacement is reduced, the sacrum must be left to itself. In some cases—for example, those with only minor compression of the sacrum—no pelvic reduction is necessary; such patients should be treated as soon as possible by active exercises in bed, and by such physiotherapeutic aids as may facilitate the active use of the muscles. In no case is the muscle paralysis so complete that deformities will arise if the patient is given exercises. Where paralysis exists, its incomplete nature is suitably dealt with by exercises against graduated resistance, together with a little radiant heat and massage. As soon as the pelvis is consolidated, usually at the end of eight weeks, walking is encouraged.

PROGNOSIS

In the lesser degrees of injury, the prognosis is good, complete recovery occurring at the end of a year; although there may be weakness in the leg and some slight permanent muscle wasting. In the severe cases, the prognosis is not good. Complete recovery of the power in the calf does not occur, and the limb is permanently weaker than its fellow. The ankle jerk may remain absent or diminished. Combined with this is frequently some elevation of the affected half of the pelvis, with consequent shortening of the lower extremity and a limp. Because of the paresis of the glutei, there may be dropping of the pelvis, when weight is taken on the affected limb. The hamstrings, although wasted, cause little disability. With the lapse of time, the limp may be disguised, but permanent partial disability is inevitable.

CASE REPORTS

Case 1. L. C. D., aged twenty-six years, was admitted to an E. M. S. Hospital on December 9, 1941. He had been sitting in a seat running along the side of an Army lorry, when it was struck by another vehicle. He had been thrown violently among his companions on the opposite side. He lost consciousness and was brought to the Hospital in mild shock, with abrasions of the face and right knee, and bruising and tenderness over the sacrum. On December 11, the patient complained of pain in the left lower extremity. On December 18, a distended bladder necessitated catheterization. This condition appears to have been a transitory disturbance, as the patient passed urine normally on admission, and there is no note of subsequent difficulty. Constipation required the use of enemata. On January 21, 1942, the patient was transferred to a fracture clinic.

Investigation showed a double pelvic fracture anteriorly through the ischiopubic rami, and another fracture through the sacrum close to the sacro-iliac joint, with elevation of the lateral mass of the sacrum (Fig. 3). The whole left half of the pelvis was raised half an inch. The left sacro-iliac joint appeared widened, but the surfaces were otherwise not displaced. He had no pain, and complained only of weakness

in the left limb. Examination showed disuse atrophy of both limbs, but, on the left, there was more obvious wasting of the calf, some wasting of the biceps femoris, and loss of tone in the glutei. The left lower limb showed three-quarters of an inch of shortening. Full exercises in bed were given, with a marked improvement in the muscle tone of both lower extremities, but with an equally marked failure of the calf on the left side to respond. On February 2, when the patient was allowed to walk for the first time, there was half an inch of wasting of the calf, and the patient could not stand on the toes of that leg.

The disability slowly improved, so that the patient was capable of moderate activity; but the weakness of the calf, diminished ankle jerk, and some loss of the bulk of the glutei remained, when he was sent to a convalescent institution on April 18, 1942. He was returned to the Army, but only for sedentary duties.

Case 2. A. B. was sitting alongside the man described in the first case report. He was unable to move after the accident, and had severe pain in the left lower extremity. He was admitted to the Hospital in mild shock, with hematuria which cleared up in two days. There was no difficulty with micturition. Pain diminished rapidly with rest in bed, but there was some constipation for the first three weeks after injury. He was transferred to a fracture clinic on January 24, 1942, seven weeks after his injury.

On examination, the patient was found to be of asthenic build, and the lower extremities particularly were wasted. There was an ulcer, two and a half by three inches, over the posterior superior iliac spine on the left. This appeared to be due to the breakdown of a hematoma. Roentgenograms showed a quadruple fracture of the pelvis, both sacro-iliac joints were widened, and there were fractures of the ischiopubic rami on both sides (Fig. 4-A). The left side of the sacrum was crushed, fissures running from the notch above, through the first and second foramina, and emerging at the margin of the sacrum just below the left sacro-iliac joint, while a small fissure ran into the third and fourth sacral foramina. On the right, a fragment of bone, corresponding to most of the area of attachment of the sacrotuberous ligament to the free border of the sacrum, was separated by a linear fracture (Fig. 4-B). Both limbs showed marked disuse atrophy, but the left was much weaker and more wasted, and there was an almost complete loss of power in the extensors of the ankle and absence of the ankle jerk. On February 3, there was still half an inch of wasting of the calf, and a small patch of anaesthesia over the left buttock, just below the iliac crest. No disturbance of sensation could be found in the thigh, leg, or foot. Roentgenographic examination showed that the whole innominate bone on the left side was swung forward, so that the posterior superior iliac spine was excessively prominent. Two fissures were present in the ala of the right ilium.

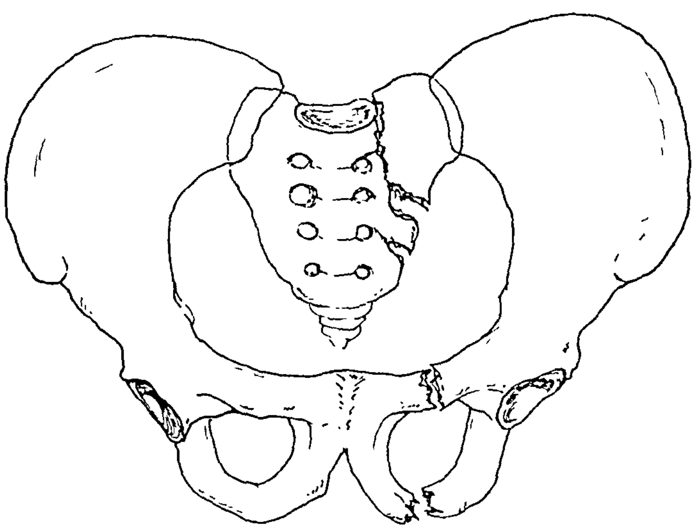


Fig. 3

Case 1. Line drawing of the pelvic and sacral fractures.

Slow progress was made with active exercises, and on March 8 the patient was allowed up, but he found difficulty in walking because of the loss of balance on the left limb. There was still half an inch of wasting of the calf and diminished ankle jerk. The patient gradually walked better; he had a pronounced limp, which was due in part to shortening, but chiefly to loss of muscle power in the glutei, a markedly wasted calf, and some loss of power in the hamstrings; the wasting of the biceps femoris was particularly marked. He was discharged from the Army on May 28, 1942.

Case 3. A. C. On March 28, 1942, the patient, aged thirty-two years, had been sitting on the side seat in a lorry, when it swerved to avoid another lorry. He was thrown out, and rendered unconscious for a short period. Taken to a nearby hospital, he was treated for shock, and a scalp wound was sutured. The diagnosis of a ruptured kidney was made, as he had hematuria which lasted for fourteen days. There was no difficulty with micturition. Roentgenograms showed a fracture of the inferior ischiopubic ramus in the usual location, and a fracture of the superior ischiopubic ramus close to the acetabulum. The fragments were elevated and overlapped (Fig. 5-A). A gross fracture of the sacrum was present, with destruction of the sacral pattern around the first, second, and third sacral foramina. A fissure, starting from the notch above on the left, ran through these foramina, and allowed elevation of the corresponding portion of the lateral mass of the sacrum, leaving a wide defect below in the lateral border opposite the third sacral foramen (Fig. 5-B). The patient complained of severe pain in the left lower extremity and foot; this was aggravated by certain movements, and partially relieved by flexion of the knee. There was numbness over the sacrum, the lateral side of the foot, and the back of the calf. The severe pain slowly diminished, and the area of numbness decreased. Three months later he was transferred to a fracture clinic.

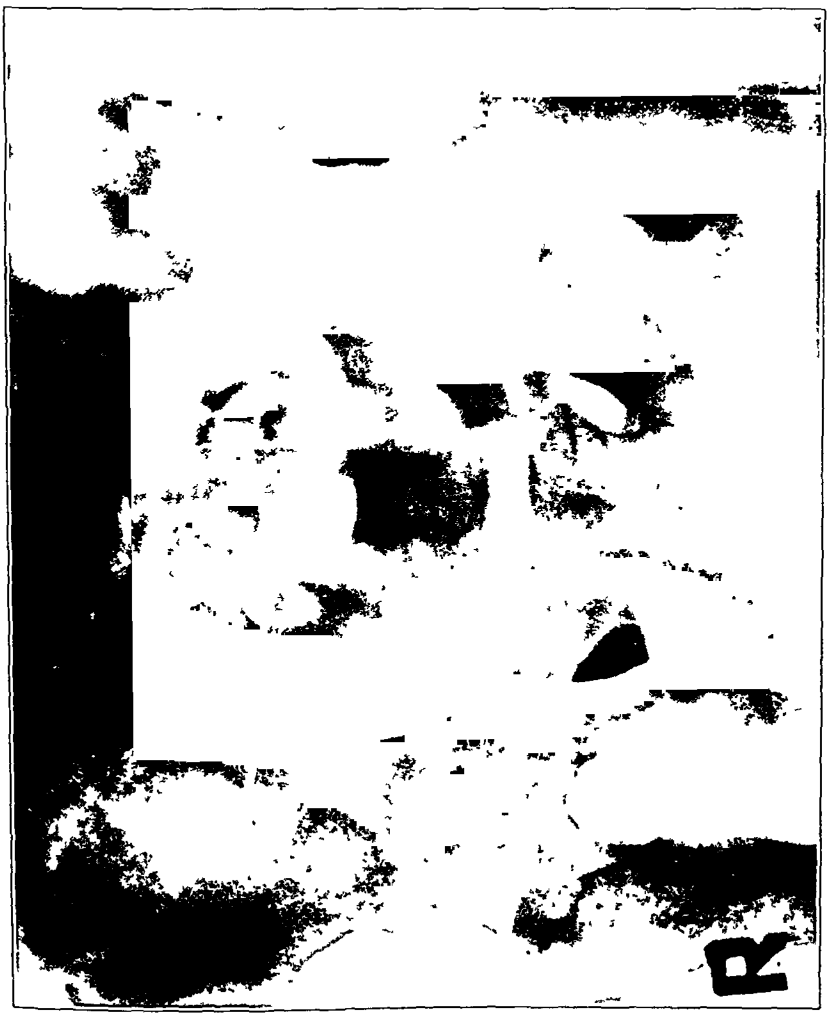


Fig. 4-A

Case 2. Note the fractures,—ilium, ischium, and pubis on the right, and sacrum, ischium, and pubis on the left

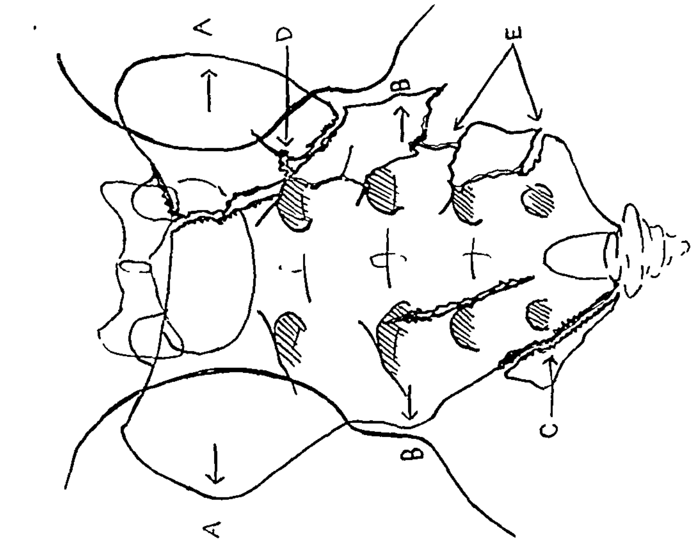


Fig. 4-B

Line drawing of the sacral fractures.

A-A and *B-B*: Note the approximation of the promontories on the left to the mid-line

C: Fracture of the sacral margin caused by the pull of the sacrotuberous and sacrospinous ligaments.

D: Marked loss of sacral pattern.

E: Fissures running from the anterior sacral foramina to the lateral margin of the sacrum

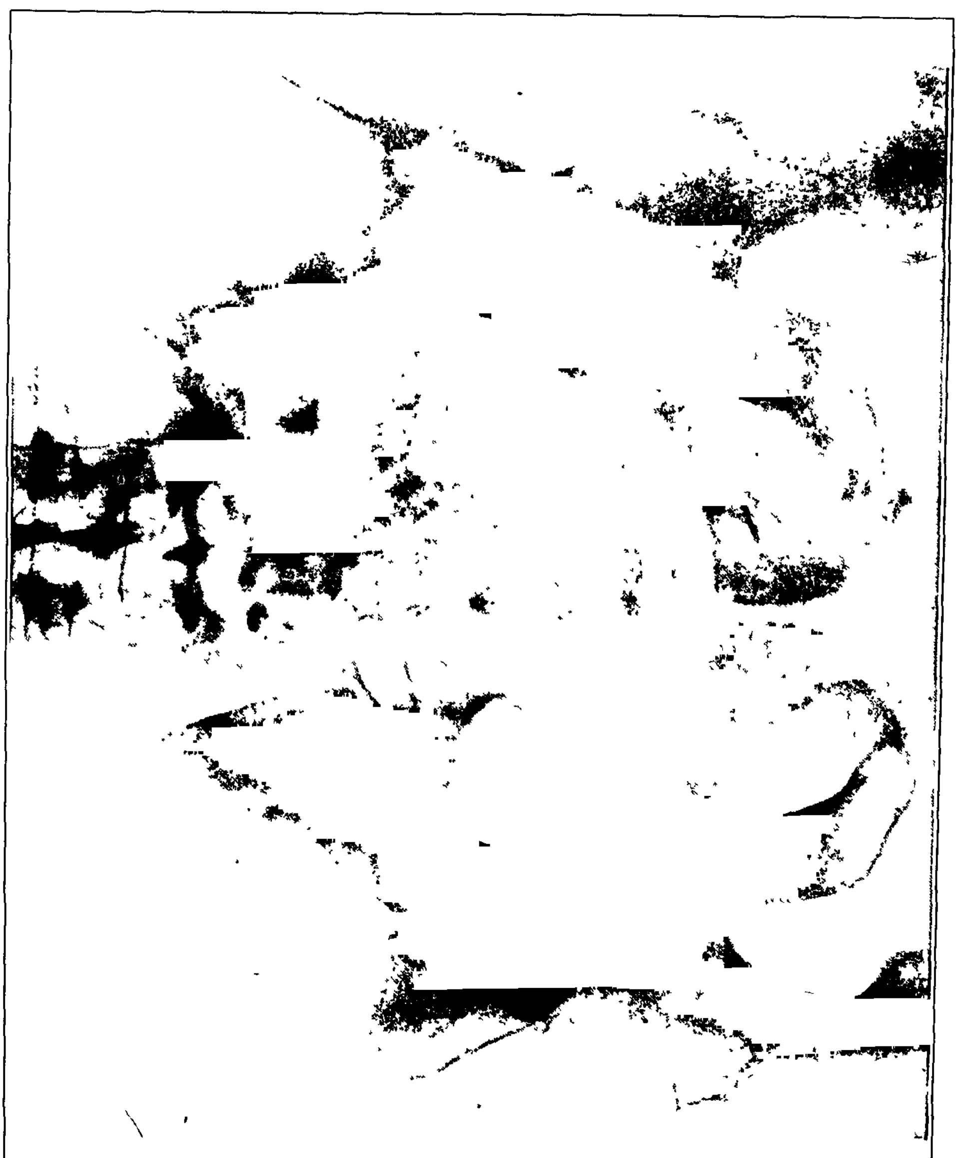


Fig. 5-A

Case 3. Note the gross destruction of the sacral pattern, and the elevation of the lateral mass of the sacrum.

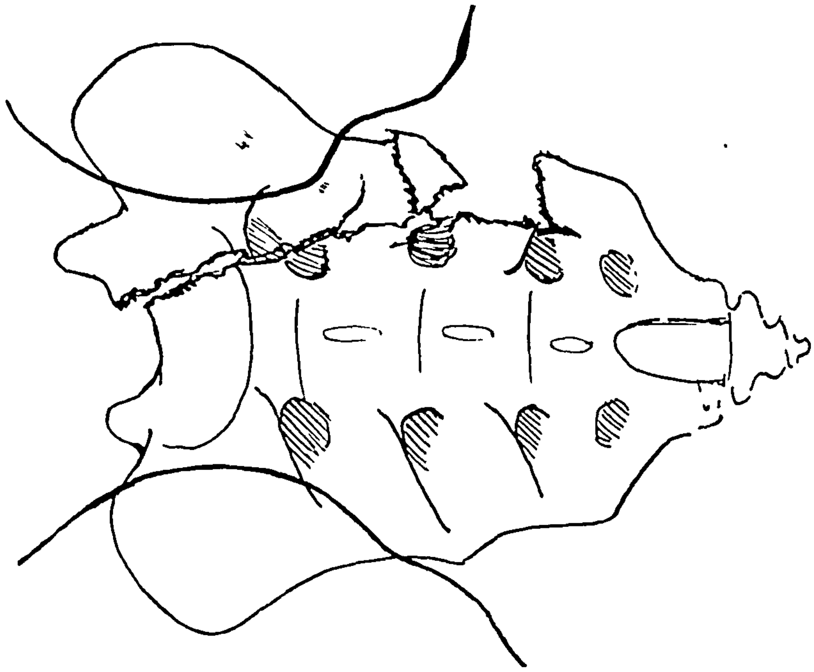


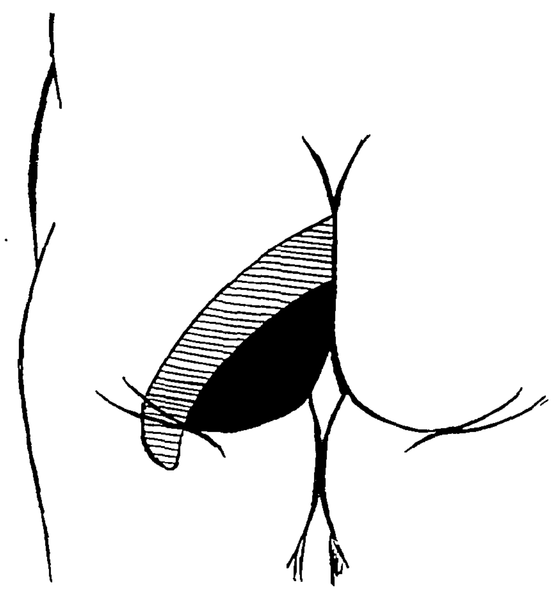
Fig. 5-B

Line drawing of the sacral fracture, showing the involvement of the left articular facet for the fifth lumbar vertebra, allowing partial spondylolisthesis.

On June 27, 1942, he was still complaining of pain in the left limb and groin and over the sacro-iliac region. Paraesthesia was now confined to the outer border of the left foot. There was wasting of the left buttock, the hamstrings, particularly the biceps femoris, in which fibrillation could be seen, and the calf. The calf was tender, and was half an inch less in circumference than the right, and there was one and a half inches of wasting in the thigh. The left lower extremity was half an inch shorter than the right, and there was a positive Trendelenburg sign. The left ankle jerk was absent. Sensory examination showed a loss of sensation to light touch and pinprick over a small area on the medial aspect of the left buttock, with a surrounding area of hyperalgesia and loss of sensation to light touch (Fig. 5-C). There was loss of sensation to light touch and blunting of sensation to pinprick over the back of the lower half of the left leg, the outer side of the foot, and part of the sole (Fig. 5-D). Fresh roentgenograms showed the presence of the fractures described, but also showed some degree of spondylolisthesis. It was considered that this was a true traumatic lesion, caused by fracture and displacement of the sacral facet of the fifth lumbar vertebra on the left. Investigation of the foot showed a loss of response to faradism of all the small muscles, with the exception of the abductor hallucis and the first interosseous. The area in which sensation to pinprick was blunted decreased slowly, until, in the fifth month, it was confined to the outer side of the fifth metatarsal, all of the fifth and half the fourth toes. Pain, of an aching character and related to activity, persisted over the lumbosacral region posteriorly, and was considered to be caused by the spondylolisthesis. The patient walked with a limp, had a positive Trendelenburg sign, and was unable to raise himself on the toes of the left foot.

At the end of the seventh month, the power in the affected limb had increased, the patient could balance on the limb, but could not raise himself on his toes. The biceps femoris was still extremely weak and wasted; the ankle jerk was absent; and the calf was still wasted. There was a return of faradic response in the small muscles of the foot. Blunting of sensation to pinprick was still present over a small area on the left buttock, while the area over the fifth toe showed hyperaesthesia only. In October 1942, he was discharged from Army.

Case 4. G. P. On February 5, 1942, this patient, aged twenty-four years, had been driving a lorry which had skidded and overturned; he had been thrown heavily against the outer side of the right hip. He sustained a sharply defined bruise over the right greater trochanter, which suggested that he had struck some narrow object. On admission, he was in mild shock, and slight hemorrhage from the urethra was noted. There was some mid-line suprapubic tenderness. A catheter was passed and blood-stained urine was first withdrawn; the urine later became clear. No evidence of perineal bruising appeared, and the catheter was withdrawn the next day; the patient subsequently passed urine normally. Examination of the right lower extremity showed no signs of neurological disturbance. Roentgenograms revealed a fracture of the tip of the greater trochanter (obviously caused by direct violence), the separation of a small flake of bone on the



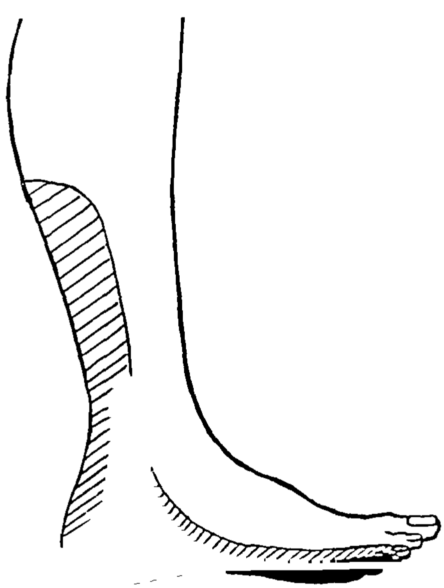


Fig. 5-C Areas of sensory loss. Fig. 5-D

Fig. 5-C: Black: The area of loss of sensation to light touch and pinprick on the left buttock.
Shaded: The surrounding zone of hyperalgesia.

Fig. 5-D: Shaded: The area of loss of sensation to light touch and blunting of sensation to pinprick on the outer surface of the foot at the end of the third month.
Black: The area of similar loss at the end of the seventh month. At the end of the year, the little toe and metatarsal area only were affected.

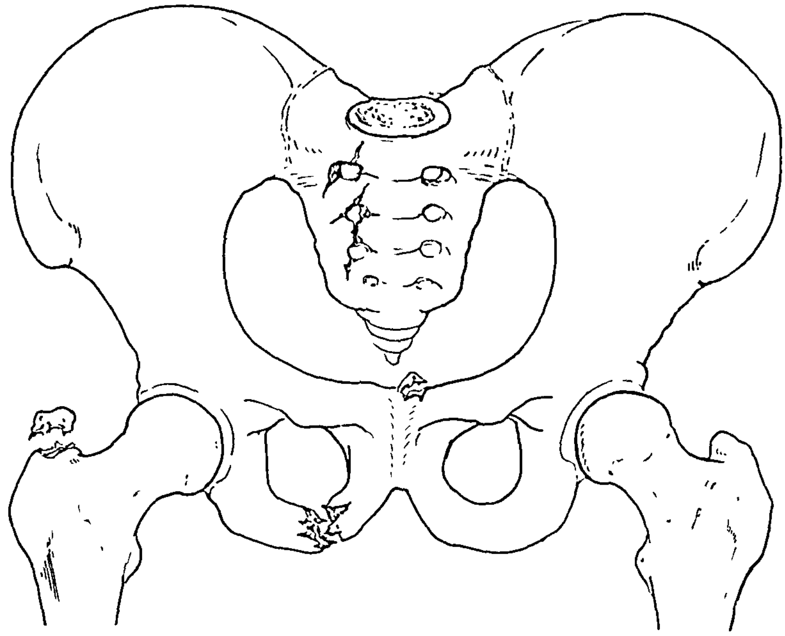


Fig. 6-A

Case 4. Showing fractures of the tip of the greater trochanter and the inferior ischiopubic ramus on the right, and the separation of a small flake of bone on the left side of the symphysis pubis.

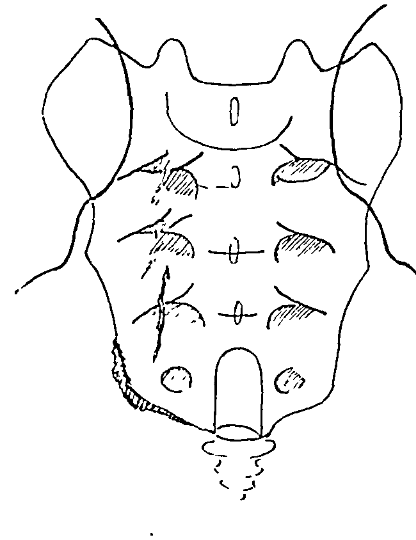


Fig. 6-B

Showing the fractures of the sacrum in detail. The appearance of the sacrum is normal in spite of multiple fissures. The cross-hatched area represents the site of new-bone formation, seen in the seventh week.

left side of the pubic symphysis (probably related to the urethral bruising), and a fracture of the inferior ischiopubic ramus on the right side, with little displacement. A crush fracture of the right side of the sacrum was indicated by loss of the sacral pattern, and by a fissure running down and out toward the outer margin of the sacrum (Fig. 6-A).

Satisfactory progress was noted until the fourteenth day, when the patient complained of shooting pains in the right limb; some loss of power in the calf, which had been suspected, became obvious; the whole of the right lower extremity was generally weaker than the left. Treatment by active exercise in bed was continued, and by the fifth week the pain had become localized to the anterior half of the sole of the right foot, which was hyperaesthetic to touch (Fig. 6-C). Wasting of the right leg continued, and in the eighth week the circumference of the calf was three-eighths of an inch less than of the left. At this period, he was allowed up, and was able to walk reasonably well, having only a slight limp due to pain. There was no shortening of the right lower extremity, and the hamstrings and glutei, although slightly reduced in bulk, could carry out normal functions. By the tenth week, the hyperaesthesia in the sole of the foot had been reduced in intensity, and the patient walked with a barely detectable limp, although there was still half an inch of wasting in the thigh and one-quarter of an inch of wasting in the calf.

Roentgenographic examination in the seventh week, prior to his getting up, showed new-bone formation along the right lower border of the sacrum, corresponding to the attachment of the sacrotuberous ligament (Fig. 6-B), producing a picture resembling that seen in (Case 2, Fig. 4-B).

On October 12, 1942, three months after admission, he was transferred to a convalescent depot for regrading.

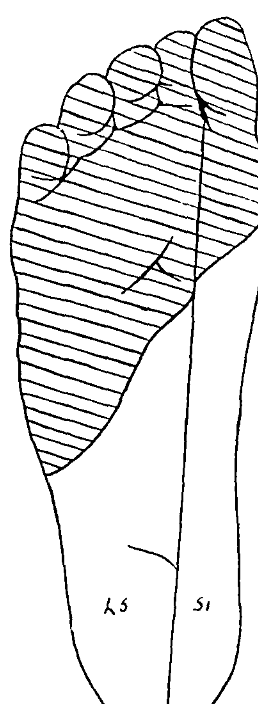


Fig. 6-C

The shaded portion shows the area of hyperaesthesia to touch. The dermatomes for the fifth lumbar and the first sacral nerve roots are indicated.

Case 5. M. T., aged twenty-six, a guardsman of powerful build, was admitted to the Hospital, unconscious after a motorcycle accident, on June 16, 1943. No evidence of injury to the skull was found, and the patient regained consciousness in six hours. He was in moderate shock. An abrasion over the chin and pain over the mandibular joints suggested that he had been knocked out by a blow on the jaw. He complained of pain in the right knee and the right side of the pelvis. An abrasion was present below the right knee, and the knee was distended with fluid and was difficult to examine because of pain and muscle spasm. Tenderness was present over the right sacro-iliac joint, and there was pain on compressing the pelvis; the patient found it impossible to turn in bed. There was no urinary disturbance. Roentgenographic examination of the knee joint was negative. The pelvis, however, showed a triple fracture (Fig. 7-A). The ischiopubic rami on both sides were fractured, and there was a loss of sacral pattern

over the right side of the sacrum, with slight narrowing of that half of the bone. There was no upward dislocation of the innominate bone. The patient was, therefore, kept flat in a fracture bed, with a balanced pelvic sling to assist in raising him. As soon as pain would permit, that is, four days after admission, a complete neurological examination was made. No sensory disturbance was found, but there was loss of the right ankle jerk. The hemarthrosis in the right knee, later on clinical examination, was found to be due to a rupture of the cruciate ligaments. Reflex wasting of the quadriceps, in spite of treatment, was, therefore, to be expected,—this exaggerated still further the appearance of wasting of the limb due to sacral-root injury.

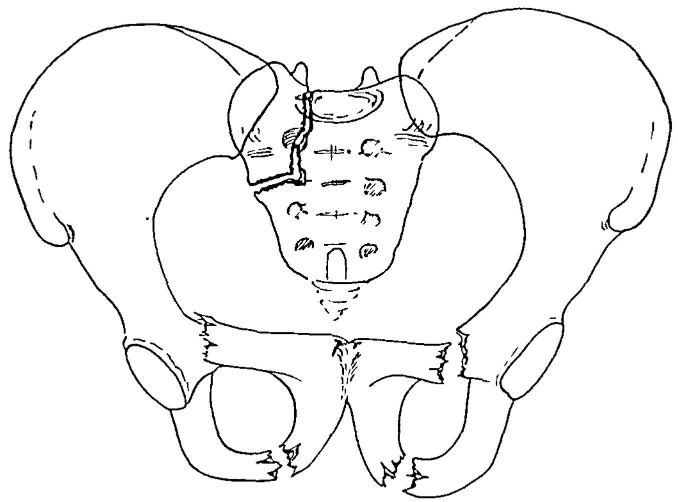


FIG. 7-A

Case 5. Line drawing of the pelvic fractures.

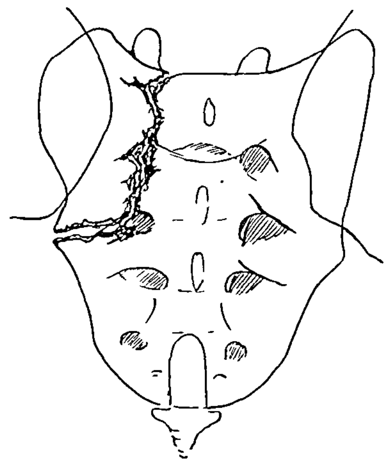


FIG. 7-B

Tracing from the roentgenogram, showing the sacral fractures in more detail.

On July 1, 1943, two weeks after injury, wasting of the right calf and muscle tenderness became marked, and continued to progress. There was complaint of numbness and tingling in the outer three toes, and a vague alteration of sensation like "sitting on a wet cloth" over the right buttock. On July 15, all the three posterior groups of muscles of the leg were wasted and tender to the touch. The ankle jerk was still absent. The weakness of the calf and the hamstrings was disproportionate to the degree of wasting, and was very marked. The biceps femoris was weak, but its contraction was visible. The muscles of the anterior compartment of the leg, the peronei, and the small muscles of the foot were normal to clinical examination and to electrical stimulation. There was a patch of altered sensation, about eight inches in length, over the popliteal space, and a similar patch over the right buttock. There was loss of sensation to pinprick in the center of these areas, and to light touch on the outside. The areas of altered sensation slowly decreased in size, until, in the eighth week, only a vague alteration to light touch remained. The wasting of the muscles, however, persisted, and the ankle jerk was still absent. At the end of the ninth week, as soon as he was free from pain, the patient, who had had exercises daily in bed, was allowed up. Movements of the right knee were full, but there was still marked wasting of the quadriceps and relaxation of the cruciate ligaments. The patient walked with a bad limp, which has steadily improved.

On September 10, 1943, the patient was sent to a convalescent depot, with a recommendation for regrading to a lower medical category. There was still wasting of the posterior groups of muscles of the leg; the ankle jerk was absent; and there was a slight limp. The patient has subsequently returned to sedentary duties.

COMMENT

Of the five cases, the third was the most severe, the patient's condition probably representing an almost complete division of the first and second sacral nerve roots. The clinical picture in this case corresponds to that which, on theoretical grounds, would be expected from complete division. The injury is more extensive than the lesion produced by division of the first sacral nerve, but includes its characteristic features.

Case 4, although less severe than the others, is interesting in showing the possibility of late onset of symptoms when there is little sacral displacement. This is probably due in part to the fact that partial paralysis of a muscle, if mild, is readily overlooked. In this case, although paralysis was suspected, because of the disproportionate loss of power

compared with the muscle bulk, definite diagnosis was not possible until muscle atrophy had made the wasting of the calf obvious. At the same time, damage to the plexus was confirmed by the occurrence of referred pain and paraesthesia in the foot.

In the first and second cases, sensory changes, which may have been present, were not recorded when the patients were first seen at other hospitals. These cases point a moral. The wasting present in both legs was attributed to disuse atrophy and no comparison of the limbs was made. Once this was done, it was obvious that there was a considerably greater loss of muscle in one leg, with paresis of specific muscle groups, and this could be readily confirmed with a tape measure. In Case 2, it is remarkable that such severe damage should have affected chiefly the motor nerves. There was only a small area of anaesthesia on the opposite buttock, probably due to superficial nerve injury. Pain, however, was marked in the early stages of the injury. Sensory changes may have cleared up before the end of the seventh week, although it is more probable that the lack of sensory change found at that time (which was present at the outset in all other cases) is due to a greater overlap of sensory disturbance than of corresponding root motor enervation.

In three of the cases, gross sacral damage was associated with severe pelvic fractures and obvious displacement. In the fourth case, the displacement was not obvious. The subsequent formation of new bone around the attachment of the sacrotuberous ligament suggested that the displacement may have been greater at the time of injury than the first roentgenogram showed, a feature probably common to all cases. The second case is interesting in drawing attention to fracture of the sacral margin by the pull of the sacrotuberous ligaments; this mechanism is confirmed by the changes noted in the fourth case.

In the fifth case, the mechanism of pelvic and sacral fracture is shown, by the site of the abrasion and damage to the cruciate ligaments, to be due to a violent blow just below the flexed knee. Such an injury is not uncommon to a motorcyclist in a collision. The slow appearance of the full and characteristic syndrome is typical, as is the disproportionate muscle wasting compared with sensory loss.

SUMMARY

The frequency of roentgenographically obvious fractures of the sacrum in association with fractures of the pelvic ring was 45 per cent. in this series of cases.

The varieties and mechanism of sacral fractures are discussed; most of these fractures are caused by leverage through the detached half of the pelvis.

The involvement of the sacrum in this type of fracture is localized around the first and second anterior and posterior foramina.

The roentgenographic features characteristic of this lesion are described.

Disturbance of the first and second sacral nerve roots produces a readily recognizable syndrome. This syndrome is characterized by sensory disturbances over the outer side of the foot, weakness of the hamstrings and glutei, marked weakness of the calf, and diminution or loss of the ankle jerk.

Recovery is slow, and permanent impairment of gait and limitation of activity may follow.

The author wishes to record his indebtedness to Dr. R. Arden Jones for assistance with the neurological examination of the patients and criticism of the article, and to Dr. F. R. Berridge for comments and advice on the roentgenography.

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THE FIXATION OF FRACTURES OF THE UPPER FEMUR AND HIP WITH THREADED, HEXAGON-HEADED, STAINLESS-STEEL SCREWS OF FIXED LENGTH*

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During the past four years, we have employed long, slender, threaded, stainless-steel screws of definite length, capped with a hexagonal head of the same material, for the fixation of fractures in the upper femur, including those in the region of the hip. The results obtained seem to justify a description of the method of treatment employed and of the construction of the screws.

CONSTRUCTION OF THE SCREWS

Figure 1-A shows the screws. They are prepared in several fixed lengths, those most frequently used being three, three and one-half, and four inches in length. These lengths have also been manufactured in three sizes,—0.125 (1/8) of an inch in diameter, 0.156 (5/32) of an inch in diameter, and 0.187 (3/16) of an inch in diameter. The first is threaded twenty-four turns to the inch; the second, twenty-four turns to the inch; and the last, twenty turns to the inch. The screw, one-eighth of an inch in diameter, is used in most cases. However, it should be pointed out that in threading this screw, a die must be used that does not cut so deeply that it unduly weakens the shaft of the screw. The screw has a sharp triangular point. The smallest size is capped with a quarter-inch hexagonal head of the same material as the shank, while the two larger sizes are capped with hexagonal nuts, three-eighths of an inch in diameter. The long diameter of the hexagonal head is also one-quarter of an inch. The head is slotted for application of the screw driver. The material used in the screw is one of the stainless steels (18 per cent. chromium, 8 to 10 per cent. nickel). Determinations of tensile strength in longitudinal-pulling tests show that the smallest screw will not give way—that is, the threads will not strip—until an average of 800 pounds has been applied; the second size will withstand 1,130 pounds; and the last size, almost 1,300 pounds. In these tests, the shank never broke, but the threads stripped. Tests of the holding power of four or five screws in experimental fractures of the central portion of the femoral neck in specimens removed from cadavera showed that a distracting force of 600 to 800 pounds was required to separate the fracture, while the screws in a similar situation would withstand a shearing force of from 500 to 1,200 pounds before the screws cut through the femoral head. The details of these tests and comparison of the results of them to the results of tests of other screws and materials used for the fixation of transcervical fractures of the upper femur will be presented in another communication. In the tests of distraction, it was found that the hexagonal heads occasionally cut through the lateral cortex of the femur at the site of entrance of the screws. Such cortical breaks always occurred when the screw had been introduced into the lateral femoral cortex in the inch immediately distal to the greatest lateral prominence of the trochanter (vastus externus line). Consequently, it has now become our practice to distribute the pressure in this area by thin, stainless-steel washers with an outer diameter of one-half inch or by a small methyl methacrylate plate. When the point of entrance of the screw was placed more inferiorly, a thicker osseous cortex was engaged, which did not give way. The maximal distracting force of 800 pounds or more would then pull the head of the femur from the screws.

* Read at a meeting of the Chicago Orthopaedic Society, April 14, 1944, and in part at a meeting of the Columbus, Ohio, Academy of Medicine, October 16, 1944.

The insertion of these screws is started with a drill, equipped with an adjustable chuck. When the entering course of the screws has been definitely determined, the drill is removed and the screw is more quickly and firmly twisted home with a brace, equipped with a quarter-inch socket attachment (Fig. 1-B).

INTERNAL FIXATION

Transcervical Fractures

It is almost universally agreed that internal fixation of transcervical fractures of the hip from the trochanteric side is preferable to arthrotomy. Moore pins and the Smith-Petersen nail offer little or no resistance to a distracting or sliding force directed in the long axis of the femoral neck. This allows intrusion and extrusion of the nail or pins. Telson

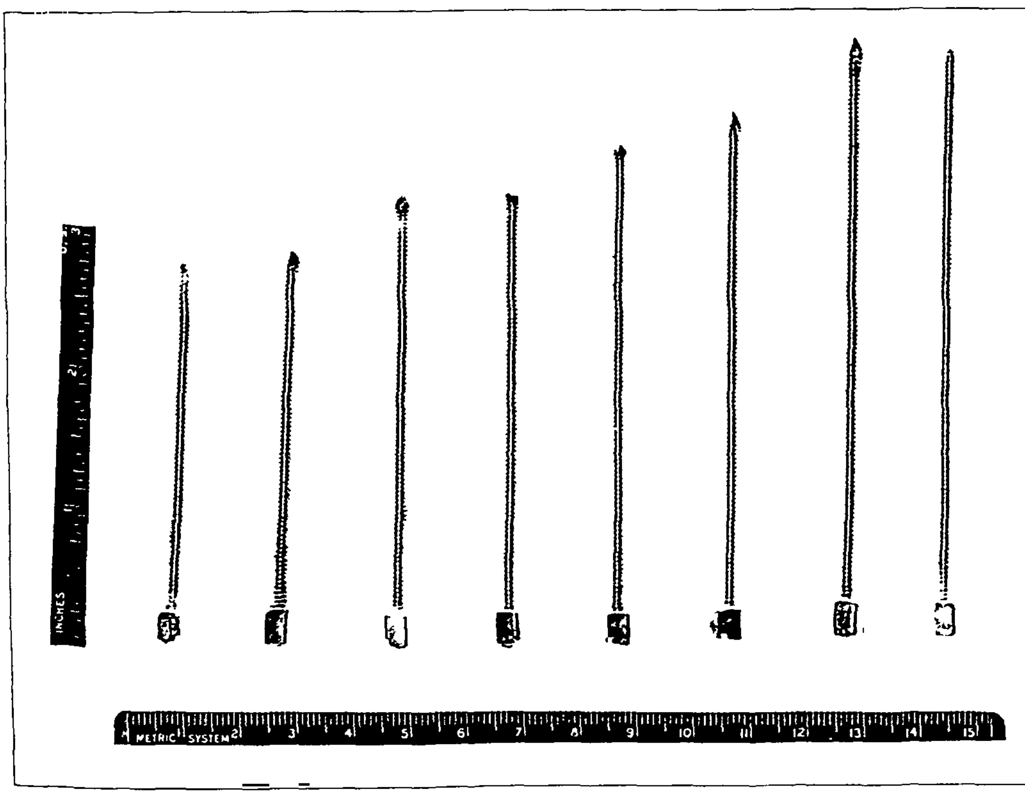

Fig. 1-A

Slender, hexagon-headed, stainless-steel screws of various lengths, as used in fixation of the transcervical femoral fractures.

Fig. 1-B

Socket brace to fit hexagon-headed screws, the heads of which are one-quarter of an inch in their transverse diameter.

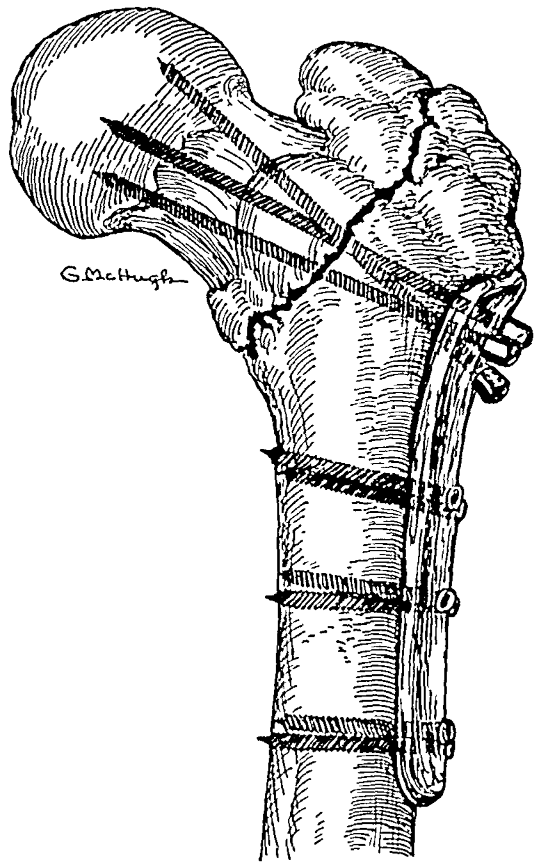

Fig. 2

Artist's sketch, showing the position of the plate and screws in a typical trochanteric fracture.

and Ransohoff, and Chester have reported satis factory experience with Kirschner wires, but i later became evident[22] that the wires migh migrate. Slender, uncapped, threaded wires hav been observed by us and by others to migrate and, in rare instances, to perforate the pelvis.

Trochanteric Fractures

Not so generally accepted is the open reduc tion and internal fixation for fractures in th trochanteric region. A high mortality has bee reported for trochanteric fractures, treated b methods ordinarily referred to as "conservative' Leydig and Brookes reported a mortality rate (39.2 per cent. in 302 cases of trochanteric fractur at the St. Louis City Hospital; Taylor, Neufelc and Janzen, 25 per cent. in 165 patients from th Los Angeles County General Hospital; Wilson 24.3 per cent. in sixty-two patients in the Massa chusetts General Hospital; Morris, 44 per cent in sixteen patients at the Charity Hospital in Nev Orleans, while the mortality in 164 cases at th Guthrie Clinic and Robert Packer Hospital (pri vate and ward cases combined) over a ten-yea period ending in 1941 has been 39.0 per cent These ratios do not tell the whole story. Com fort to the patient in freedom of motion in bed, transfer to the wheel chair, and earl crutch ambulation with consequent lack of complications, including decubitus, are th chief advantages of internal fixation. Two of our patients, who have been unfortunat enough to have had earlier hip fractures treated "conservatively", stated that they prefe the internal fixation.

Key was the first to attempt internal fixation in these fractures, and to report some of the problems involved. It was his opinion that the low trochanteric fractures, in which the lateral cortical shell was comminuted or was carried with the upper fragment, could be fixed only by wiring. Since that time the use of the Thornton plate, in conjunction with the Smith-Petersen nail and other devices, has demonstrated that internal fixation which prevents adduction and rotation of the distal fragment will maintain reduction.

The principles enumerated above have been met by different men with various devices.

The author's screws, similar to but longer and more slender than those described by Geckler for the fixation of transcervical fractures, depend upon fixation in the lateral femoral cortex to maintain abduction without rotation, and hence the proper cervical angle. In this report are given our experiences with fixation of these fractures with a molded plate of non-irritating plastic (methyl methacrylate), fixed to the reduced fragments with stainless-steel screws of the construction described. Figure 2 shows the diagrammatic application of the principle.

The trochanteric fractures are a heterogeneous group, varying from a simple fracture at the base of the femoral neck (just without or at the insertion of the capsule) to complex comminuted fractures of the trochanters. These latter fractures in turn grade off into the comminuted and spiral subtrochanteric fractures.

The results reported by others in the internal fixation of trochanteric fractures have been encouraging: Morris reported 21.4 per cent. mortality in twenty-eight cases at the

TABLE I

RESULTS IN THE TREATMENT OF FRESH * TRANSCERVICAL FRACTURES WITH STAINLESS-STEEL SCREWS (THIRTY-FIVE CASES)

Result	No. of Cases	Per Cent.
Satisfactory union with a viable head	31	88.6
Early necrosis of the femoral head (minimal period of follow-up, 1 year; maximal follow-up, 3 years)	0	0.0
Union by osteotomy, performed within six months of fracture	3	8.6
Non-union †	1	2.8
Immediate hospital mortality	0	0.0
Mortality within first year after pinning (from unrelated causes)	0	0.0

* All but two patients were brought to the Hospital on the day of the fracture,—the majority within four hours. The other two patients were seen on the second day.

† The non-union was caused by an unsatisfactory primary reduction. It was thought unwise to attempt second reduction and fixation, since the patient was a poor operative risk and was blind and bedridden.

Charity Hospital, New Orleans; Key, a "lowered mortality"; Jewett, no mortality in five cases; and Thatcher, one death among thirteen patients who were operated upon. Moore reported forty-one cases fixed with the blade-plate out of a total of eighty-three cases of trochanteric fractures treated by open operation without a fatality. The mortality rate in our series was 11.1 per cent. (five out of forty-five cases), but the causes of fatality were the usual ones in elderly patients who had not been operated upon, and occurred several weeks after the operation. None of these fatalities occurred in private patients. This mortality is less than one-third that observed in a similar group of patients in the same hospital, who had been treated in previous years by "conservative" methods (Table II). The average hospital stay of eighteen patients with trochanteric fracture treated by operation in Morris's series was twenty-nine and one-half days; the average stay of forty surviving patients in this series was forty days.

MANAGEMENT OF THE PATIENT AND OPERATIVE TECHNIQUE

Patients who have sustained hip fractures are considered to be emergency cases. As soon as roentgenograms of the hip have been made, the patient is transferred directly to a fracture bed, and the Thomas or other ring splint, which has been used for emergency transportation, is removed. Fifty to eighty cubic centimeters of 0.5 per cent. procaine is injected about the hip; traction is applied through a Steinmann pin inserted above the condyles of the femur; and the limb is supported upon a Braun frame. That reduction takes place within a few hours of the time the patient is thus arranged in bed can be demonstrated by roentgenograms taken the next morning. Reduction may be expected in all cases except certain transcervical fractures which offer resistance to reduction by traction, because of their peculiar displacement (usually posterior rotation of the proximal

TABLE II

RESULTS IN THE TREATMENT OF TROCHANTERIC FRACTURES WITH METHYL METHACRYLATE PLATES AND STAINLESS-STEEL SCREWS (FORTY-FIVE CASES) *†

Result	No. of Cases	Per Cent.
Satisfactory union without shortening	40	88.8
Necrosis of the femoral head	0	0.0
Early coxa vara, detected by routine roentgenograms, and subsequently treated by additional traction in bed	3‡	6.6

* The immediate hospital mortality from the usual causes in patients of advanced years and unrelated to the operation was five cases, or 11.1 per cent.

† Additional mortality occurring within two years of leaving the Hospital (from unrelated causes) was ten cases, or 22.2 per cent.

‡ These cases were included in the forty, because the end result was good.

FIG. 3-A

FIG. 3-B

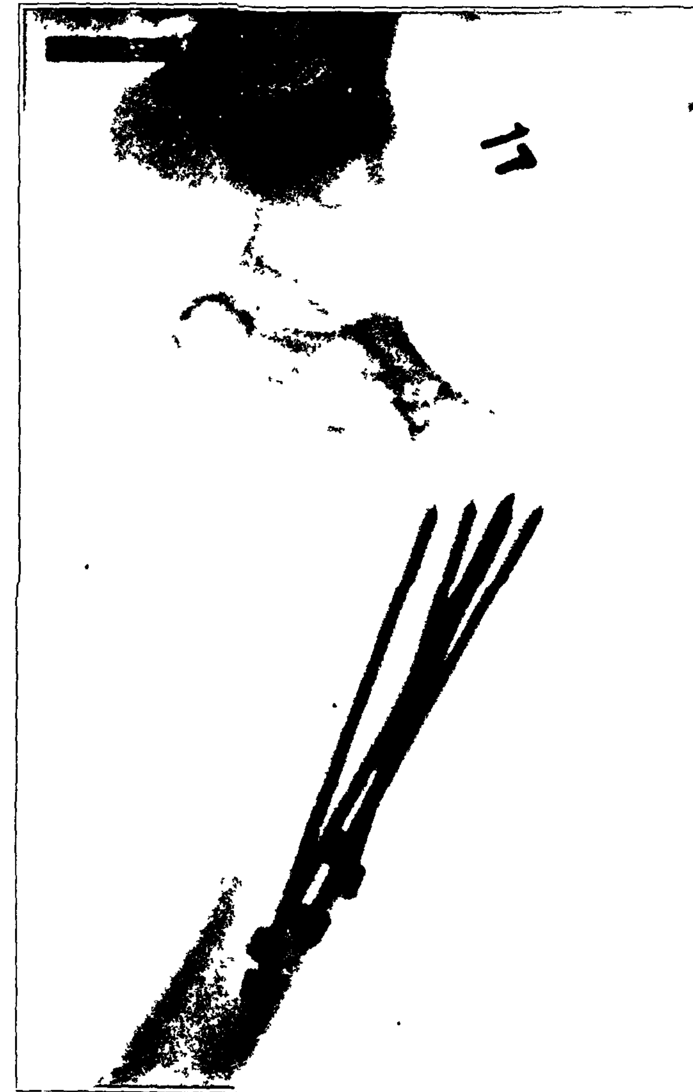

FIG. 3-C

Case 1. Roentgenograms of a transcervical fracture in a woman, sixty-nine years old. Firm osseous union was obtained in four to six months following immobilization by five stainless-steel screws.

Fig. 3-A. Roentgenogram taken on admission to the Hospital.

Figs. 3-B and 3-C. Anteroposterior and lateral roentgenograms taken seven weeks after operation.

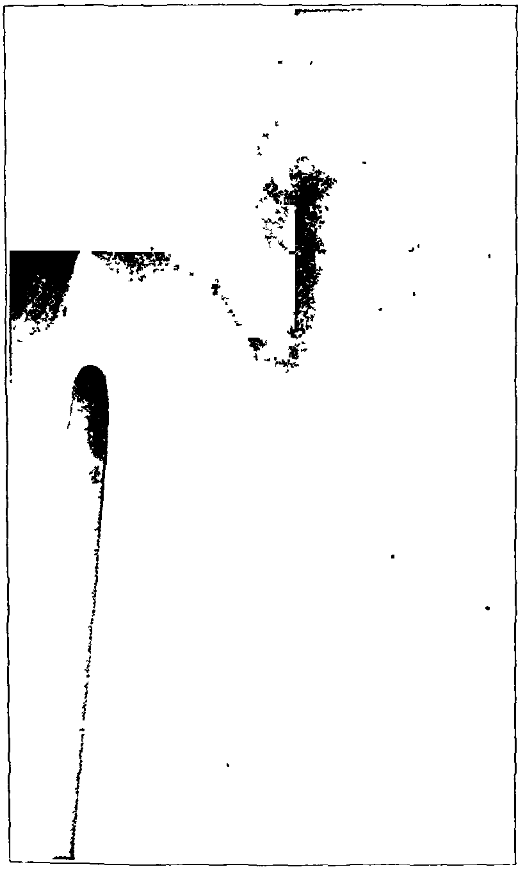

FIG. 4-A

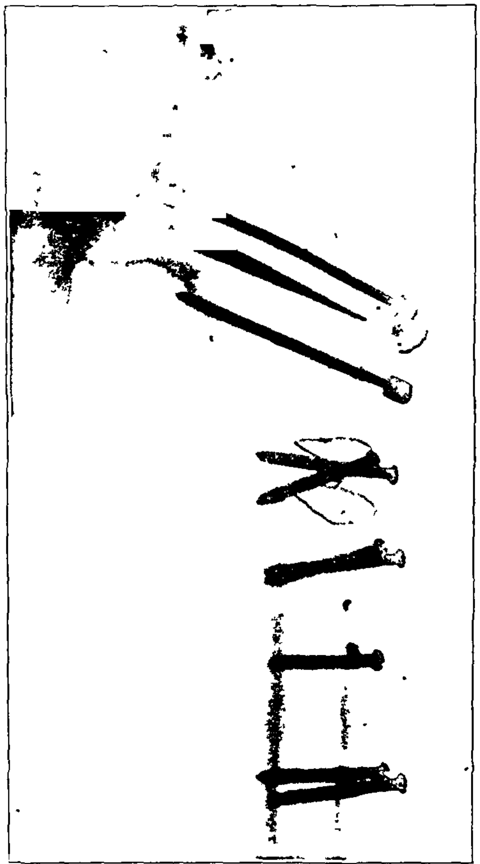

FIG. 4-B

Case 2. *Preoperative and postoperative roentgenograms of a double fracture, with an intermediate free fragment. The superior fracture line is transcervical, while the inferior fracture line is a combination trochanteric and spiral subtrochanteric fracture. The long five-inch methyl methacrylate plate was used, and the inferior tip of the superior fragment was anchored at the lower fracture line by means of two loops of stainless-steel wire.*

fragment). The open reduction is carried out with the patient in bed in the operating room (Fig. 5); a wooden cassette tunnel which is transparent to roentgen rays, is placed beneath the hips. The day of operation varies from one to four days following the fracture. It is our experience that one-third of these elderly patients have diabetes mellitus, and almost all of them have a moderate degree of secondary anaemia. Every patient routinely receives a blood transfusion of 500 cubic centimeters following operation; some patients receive preoperative transfusions and more than one transfusion following operation. We consider the transfusions important, although shock, as evidenced by a reduced blood pressure, is seldom seen. Following operation, most patients are out of bed in the wheel chair for a few hours daily, but ambulation, even with crutches, is not allowed for three months in patients who have suffered transcervical fractures, and for eight weeks in the case of those with trochanteric fractures. In complicated fractures, the patients are kept recumbent, without being allowed in a wheel chair, for fourteen to sixteen weeks. After six weeks, all patients are given active and passive knee exercises on the Böhler exercising frame.

DISCUSSION AND RESULTS

The results of the treatment of thirty-five cases of fresh transcervical fracture are given in Table I, from which it is seen that we have obtained satisfactory union with a viable head in 88.6 per cent. of the cases. If an open fracture line is still present six months

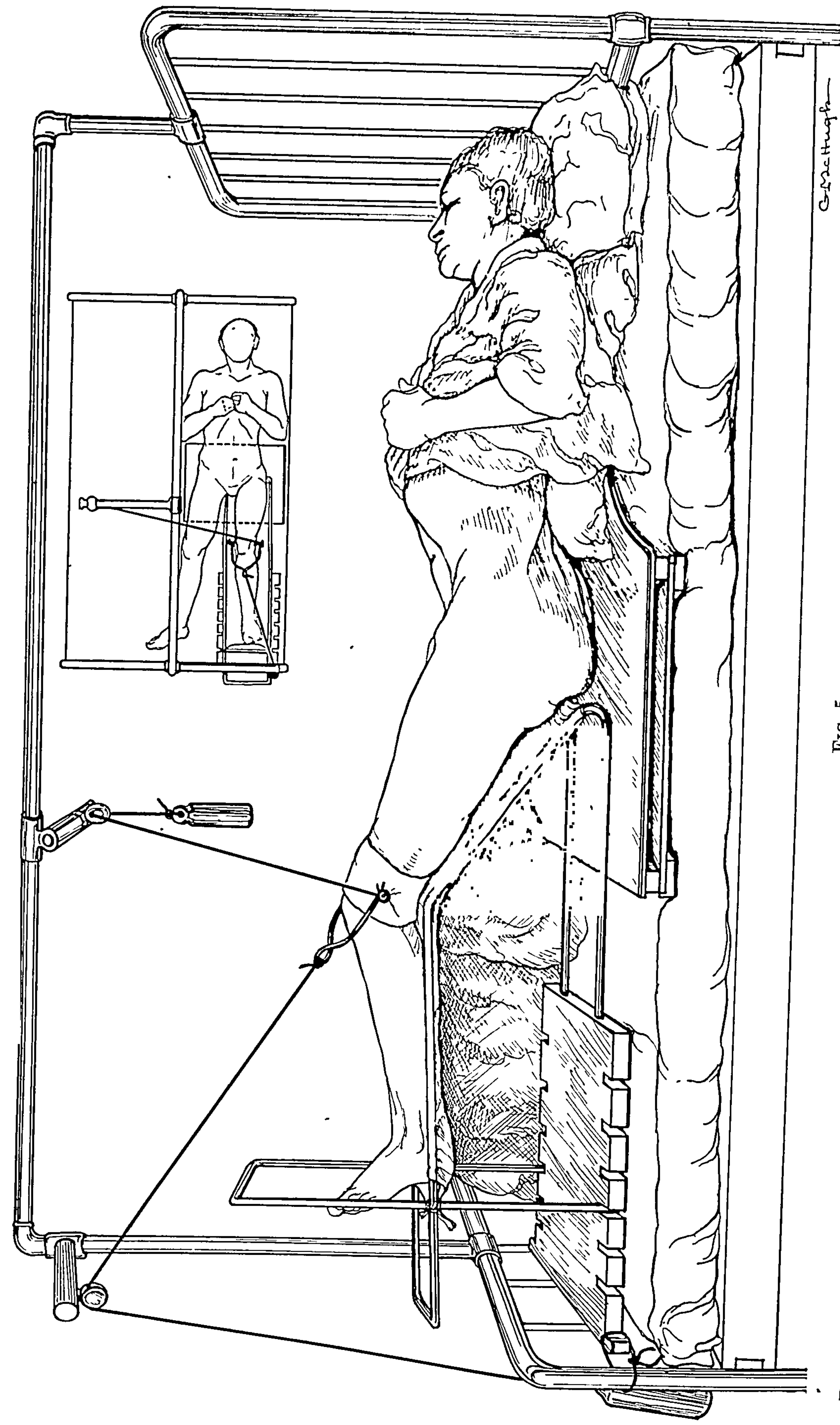

FIG. 5

Drawing, showing the position of the patient in bed at the time of the operation. The limb and the site of the fracture are immobilized by skeletal traction on the Braun frame. A wooden cassette holder which is transparent to roentgen rays, is beneath the hips to facilitate the taking of roentgenograms during the operation.

after operation, it is our practice to remove the screws and perform a subtrochanteric osteotomy, fixing the fragments with the Moore-Blount blade-plate. If three cases in our series, which were subsequently treated by osteotomy, are included, then satisfactory union with a viable head was secured in 97.1 per cent. The early reduction that we were able to secure in these cases presumably caused a minimal interference with the blood supply to the head along vessels which remain in the untorn portion of the reflected capsule of the neck, this possibly being the reason for the non-occurrence of early necrosis of the femoral head. This percentage of union in this type of fracture compares well with those listed in Callahan's review in 1939, which summarized the results obtained by various authors to that date. Since then, Cleveland has reported osseous union in 86 per cent.; Felsenreich, in 93 per cent.; Henderson, in 81 per cent.; King, in 93 per cent.; Semb, in 94 per cent.; and Valls and Lagomarsino, in 82 per cent. All utilized the Smith-Petersen three-flanged nail. Moore has reported 96 per cent. union, utilizing his special nails. The percentages of union listed above are based on the number of patients who survived the period of hospitalization.

The special advantage in the use of a threaded appliance is the elimination of all motion following fixation. We have had no instances of "absorption of the neck" and, therefore, no instances of intrusion of the fixation appliance through the femoral head and acetabulum, as is occasionally seen when non-threaded appliances are used. Tests performed upon experimental fractures of the neck of the femur in moist cadaver specimens indicate that the best fixation is secured when the screws are placed in the periphery of the neck, especially when two or more screws are placed just within the inferior cortex of the neck in a diagonal direction from a point several centimeters below the vastus externus line. This plan has been followed in the cases included in this report.

Table II shows that we secured satisfactory union without shortening and without additional treatment in 88.8 per cent. of the cases (forty out of forty-five cases) of trochanteric fractures. This includes three cases in which the fixation did not appear to be adequate enough to prevent the recurrence of slight coxa vara, and which were subsequently treated by additional traction in recumbency, with a good result. Whether or not the mortality before and after leaving the Hospital indicates that the patients suffering from trochanteric fractures are more fragile than those suffering from transcervical fracture, as is claimed by certain authors [13, 26], cannot be shown conclusively by the small number of cases of this report (Table II). There was no instance of decubitus, thrombophlebitis, or pneumonia among the patients suffering from trochanteric fractures. Their ability to be about in a wheel chair, free from traction, a number of hours each day contributed to their well being.

CONCLUSIONS

1. A new type of slender, long, threaded, stainless-steel screw has been described. The advantage of a screw in the fixation of hip fractures is that it obtains and holds impaction of the fragments.

2. The upper lateral femoral cortex is the site of counterpressure for this impacting force, which should be diffused by steel washers or plastic plates.

3. In the fixation of trochanteric fractures, it is necessary to use a plate extension, fixed by the screws to the lateral cortex of the upper femoral shaft to maintain internal rotation, and to counteract the tendency to redisplacement.

4. The important principles in the management of patients with these fractures are early reduction, fixation following an anatomical replacement of fragments, a postoperative regimen sufficiently flexible to avoid decubitus and other ills of prolonged and enforced recumbency, and the avoidance of ambulation (even with crutches) until union is well under way.

5. The results in thirty-five cases of fresh transcervical fractures include satisfactory

union with a viable head in 88.6 per cent. of cases. Union was secured by subtrochanteric osteotomy (the necessity of the operation indicated by an open fracture line in the roentgenogram six months after fixation) in three additional cases or a total of 97.2 per cent. There were no fatalities in this series, and no cases of early necrosis of the femoral head. Since the cases have been observed for only one to three years after operation, no statements can be made about late necrosis of the femoral head.

6. The results in forty-five cases of trochanteric fractures include satisfactory union without shortening in 88.8 per cent. Mortality from the usual causes among aged patients was observed in this group in five cases (11.1 per cent.). This represents a reduction of mortality to less than one-third that observed in a larger series of cases treated "conservatively" in the same Hospital over a ten-year period preceding this study.

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MEASUREMENT OF MUSCLE STRENGTH

BY HENRY MILCH, M.D., NEW YORK, N. Y.

Destructive criticism has never been too highly appreciated, and negative discoveries have never won the Nobel Prize. Yet each may play a valuable and vital rôle in the progress of science and may serve to avoid waste of effort that could profitably be directed along other lines. This seems to be true of present methods of estimating muscle power, especially with respect to the possibility of muscle transplantation.

Though the practice of muscle transplantation has by far not fulfilled the earliest hopes and expectations with which it was received, it still remains one of the major methods in the effort to rehabilitate the paralytic patient. Many pitfalls of a technical nature beset its path, but probably the most serious is the inability accurately to gauge the actual strength of the patient's remaining musculature. Without such prerequisite estimates, it would seem impossible to avoid the danger of inadequately correcting the existing deformity, or, by overcorrecting, of creating the opposite deformity. Without such records, the merit of methods already devised to improve the functional capacity of the patient cannot be critically evaluated or a rational therapy established.

The evident need for such data is indicated by the elaborate muscle charts which have been made a part of the medical history of paralytic patients. Though such charts may have value for comparative purposes in any given individual, though they may permit of analytical study of certain types of muscle imbalance, it must, however, be seriously questioned whether they represent what they purport. Do such charts, even when accurate, really give information as to the *actual* strength of muscles? Is it possible to measure muscle strength under ordinary clinical conditions? Are such measurements as are obtained directly applicable to the problems of the orthopaedic surgeon? The answer to these questions appears to be in the negative. In consequence, it seems that the value of these charts must be accepted within much narrower limits than has usually been accorded them.

It is not unlikely that a large part of the difficulty arises from a confusing equivalence of the concepts of "muscle strength", with that of "work done by muscle". Since "work

done" or torque is, by definition, the result of muscular strength acting upon a lever arm, it is clear that the measure of torque cannot by any means be considered as the measure of muscle strength. For practical purposes, this differentiation is of paramount importance. It is muscle torque of which the patient becomes aware, but it is muscle strength which the surgeon transplants, with the object of modifying torque.

The determination of muscle strength implies the ability to measure the strength of an isolated muscle-nerve unit. Except in laboratory animals under experimental conditions, such observations have been impossible by ordinary clinical methods. Some progress in the solution of the clinical problem has recently been achieved by the study of electromyograms made with coaxial needle electrodes. In general, it has been found that muscle activity is characterized by the generation of a diphasic current which can be measured and recorded. Hoefer and Putnam reported that, in normal resting muscles, no such currents could be recorded. On the other hand Hoefer noted that "effort and the frequency and height of action potentials are roughly proportionate". Watkins, Brazier, and Schwab[1] noted that "action potentials were studied during voluntary contractions such as are required during an ergographic test. The voltage of these discharges was found to be proportional to the degree of strength and gave indication of the rate of restoration of function." However, neither by the measurement of electric potential nor by the determination of voltage-capacity curves were they able to establish a numerical relationship between the strength of any given muscle and the observed electrical phenomena. To estimate the so-called strength of the muscle, recourse had still to be made to a refined ergographic apparatus[3].

The determination of work capacity lies at the basis of all present methods of measuring muscle strength. For the purpose of comparing the degree of improvement in any given muscle, a quantitative ergogram may have definite value; but fundamentally it gives no more objective determination of individual muscle strength than is obtained by the simplest clinical method in which the muscles are roughly classified as falling into one of a varying number of subgroups. The lowest grade, zero, is given to those muscles in which there is complete absence of power. The highest, grade six, is given to those in which the muscle power is normal. The intermediate grades are assigned categorically to muscles which possess the power of movement; of movement against gravity; of movement against resistance; and so on. Primarily, the objection to this system of notation has been its subjective character. The effort to eliminate such estimates in favor of more objective determinations has naturally led to the development of elaborate and ingenious measuring devices. While admitting the desirability of objective observations, it is questionable whether resolution of the difficulty has been advanced in any notable degree by the use of so-called scientific methods. The high degree of elegance which the more recent efforts have reached cannot ignore the fact that earlier and equally clever attempts at mechanical solution of the problem have met with neither success nor universal approval.

The reason for this is not far to seek. Except in the hypothetically isolated muscle-nerve unit, work is normally accomplished by synergistic action of several muscles or muscle groups. Each muscle may have several components of action and each supplies only a small component of the action under study. Since it is impossible to determine at any given moment the particular contribution of each of the synergists, it is evident that the tabulation of individual muscle strength is almost wholly valueless. It is the magnitude of flexion, extension, adduction, and abduction around a joint axis, rather than the power of the individual flexor, extensor, or adductor crossing the joint which can be recorded. The ergographic record obtained by any method is the resultant of many muscle actions, rather than the measure of a single muscle force. This is a matter of primary importance, and leads logically to the necessity for determining the meaning of the observed numerical value of this resultant.

Smooth, physiological muscle action implies the synergism of antagonist as well as

therapy can be instituted, but widely differing results may be obtained. In one patient, improper treatment might be followed by an actual decrease in the strength of the extensors from 35.0 to 10.0 units (the flexors remaining unaffected at a strength of 50.0). On the ergograph, the strength of the extensors would seem to have been decreased to 5.0 (10 minus 5) units, while the flexors would appear to have increased somewhat in strength to 49.0 (50 minus 1) units. The disappointment of the examiner at the apparent sixfold decrease in the power of the extensors would be with as little basis in fact, as his unwarranted satisfaction at the deceptive increase in the power of the flexors.

Under other circumstances, the actual strength of the extensors might have increased to 90, while the flexors remained unchanged. The measuring device would seem to indicate that, along with the marked increase in the extensors to 85.0 (90 minus 5) units, there had occurred a real decrease in the strength of the flexors to 41.0 (50 minus 9) units. Though the complete reversal of the muscle imbalance would have been clearly demonstrated, no small part of this would erroneously be attributed to an illusory decrease in flexor strength.

Examples such as these could be multiplied, but to no purpose other than to direct attention to the extreme caution with which such apparently objective observations must be interpreted. If this be true for measurements made for purposes of comparison, it is true to an even greater degree when such measurements are made the basis of surgical intervention. In a hypothetical case of flexion contracture due to a muscle imbalance between flexors (actual strength 90 units) and extensors (actual strength 50 units), the real difference would be 40 units. Making due allowance for the effect of tonic resistance, meter readings would indicate a flexor power of 85.0 (90 minus 5) units, an extensor power of 41.0 (50 minus 9) units, and a flexor preponderance of 44 units. Accepting these readings at their face value, it would seem that muscle balance at 63 units could be effected by a transfer of 22 units from the flexor to the extensor group. However, by actually transferring 22 units of muscle power from the flexors to the extensors, the real value of the flexors would be reduced from 90 to 68 units, while the real strength of the extensors would be increased from 50 to 72 units. In fact, the flexor contracture will have been converted into an extensor contracture. On the ergograph, the extensors would register as 72.0 minus 6.8, or 65.2 units. The flexors would register as 68.0 minus 7.2, or 60.8 units. The actual extensor preponderance of 4 units would appear on the measuring device to be equal to 4.4 units.

Consideration of these different drawbacks make the efforts at precision measurement of muscle strength by ergographic methods somewhat futile. But even these become relatively unimportant, when the problem is viewed in the perspective of those other factors which exert a dominating effect on the outcome of muscle transplantation. The work performed by any muscle depends not only upon its power, but upon the angle of application of the power upon the motivated lever arm and the length of the lever through which the power is applied. It is greatest when applied at right angles to the lever arm, and, in general, is expressed by the formula $P' = P \textit{ sine } x$. The value of the angle x is to be determined, not by the angle of insertion of the tendon into a given bone, but by its inclination to the lever arm, which is the resultant of all the bones between the muscle insertion and the axis of rotation at the joint. Axial deviations of this nature may so profoundly modify the effective power of a transplanted muscle that the quantitative measurement of its original position cannot be accorded any greater dignity than that of historical interest for all other positions.

Similarly, any change in the length of the lever arm upon which the muscle works will completely alter any judgments made on the basis of preoperative measurement of muscle strength. Since work done is equal to the product of the power by the length of the lever arm ($W = P \times L$), a relatively slight variation in L may lead to a totally unexpected change in the result desired. Thus, if a muscle, normally inserted one inch from its ful-

crum, were to be inserted only one-half inch closer to its new axis of motion, the power of the transplanted muscle would be reduced to half. An opposite variation would increase the muscle strength by an amount proportional to the increase in the length of the lever arms. Faced with the possibility of such wide variations, surgical procedures would have to be carried out with theodolite precision to be commensurate with the supposed accuracy of muscle-strength determinations.

The inability accurately to control or positively to determine all of these factors markedly narrows the field of application of the usual type of muscle-strength determinations. While the possibility exists that, in the future, measurements made by the use of some other principle may be devised, the methods at present employed must be accepted merely as more or less accurate clinical estimates of muscle strength. In the respect that they tend to minimize the subjective character of present methods, they represent some advance and may serve for purposes of comparison. Insofar as the actual measurement of individual muscle strength is concerned, the hope placed in ergographic determinations appears to be entirely chimerical. The pseudoscientific enumeration of the work capacity of a long list of individual muscles as a basis for surgical intervention is misleading and should be discontinued. At most, muscle charts should indicate the relative strength of flexion, extension, adduction, abduction, or rotation possible at the joint under consideration. They can never be elaborated so as to replace clinical judgment, which must finally be brought to the analysis of the surgical problem. The decision as to the availability or desirability of any muscle transplant still remains a question of individual surgical judgment. No amount of objective measurement of work capacity can be substituted for the subjective estimate of the experienced surgeon.

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AN OPERATION FOR THE CORRECTION OF LOCKING OF THE PROXIMAL INTERPHALANGEAL JOINT OF FINGER IN HYPEREXTENSION

BY MAJOR JOHN T. BATE

Medical Corps, Army of the United States

J. G. R., an aviator, was admitted to Thayer General Hospital January 17, 1944, complaining that he was unable to taxi a four-motored plane satisfactorily, because of locking in hyperextension of the proximal interphalangeal joint of the right fifth finger. To properly control the plane, it was necessary to grasp a control instrument with the right hand, using the index finger to regulate the motor on the extreme left, and the fifth finger to regulate the motor on the extreme right. When he quickly grasped this instrument (a type of throttle), the fifth finger would lock. He could not flex the finger again, until he had used his left hand to start the flexion. It was then possible to actively continue the flexion to its normal completion.

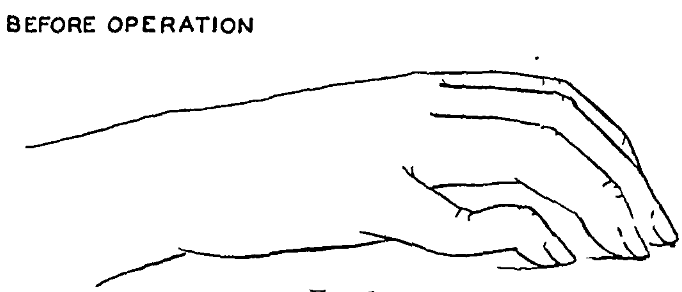

FIG. 1

Drawing showing the fifth finger locked at the proximal interphalangeal joint.

FIG. 2

Roentgenogram showing the position in which locking occurred.

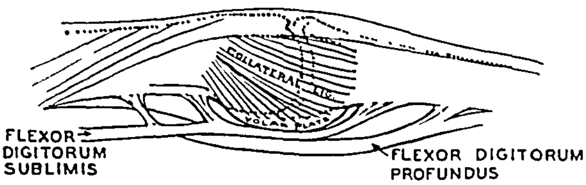

Fig. 3

Diagrammatic sketch showing the anatomy of the proximal interphalangeal joint of the finger.

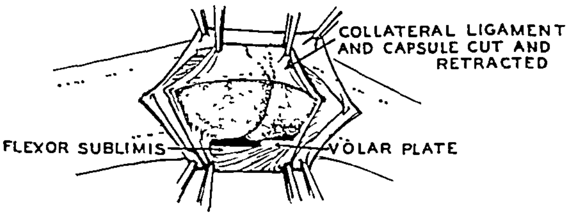

Fig. 5

Drawing of the tear on the volar portion of the capsule.

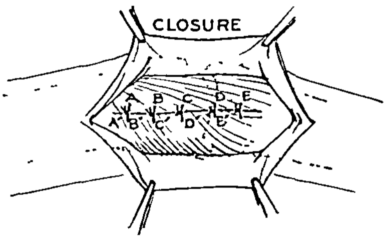

Fig. 7

Sketch illustrating the suturing of the lateral capsule by a method which shortens the anterior portion of this part of the capsule.

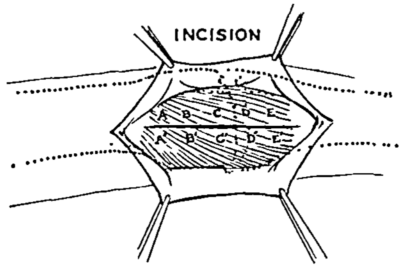

Fig. 4

Sketch showing the line of incision through the lateral part of the capsule of the proximal interphalangeal joint. The lettering helps to illustrate the method of repair (See Fig. 7).

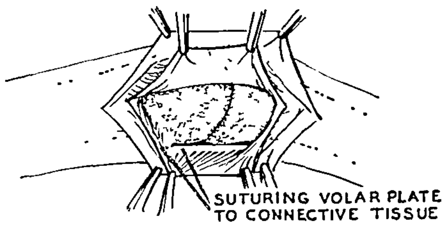

Fig. 6

Drawing showing the repair of the volar plate of the capsule.

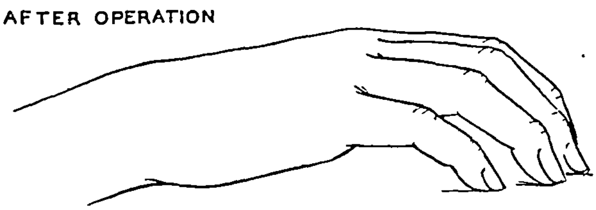

Fig. 8

Sketch showing the final result of the operation.

As we had not previously encountered this condition, and were unable to find a description of its repair in the literature, considerable thought was devoted to the problem because the officer's army and civil aviation future depended on its successful solution.

His history revealed that on August 4, 1943, while engaged in basket-ball practice, he had been struck on the end of the right little finger with a basket ball. He reported to sick call and the finger was splinted; no roentgenogram had been taken. He continued on duty, but noticed that the finger was easily injured thereafter, and that the proximal interphalangeal joint remained swollen.

About October 24, 1943, he had again injured the right fifth finger at the proximal interphalangeal joint while playing baseball. He was not wearing a splint at this time.

Since October 1943, he had had marked instability of the right little finger, and he had been unable to use it to control the throttle on a four-motored plane. The finger frequently came out of joint, was sore, and greatly interfered with duty.

Physical examination was negative except that the right hand showed marked instability of the proximal phalangeal joint of the fifth digit. Forced flexion produced discomfort in this joint. Extension caused the joint to push forward into hyperextension of about 15 degrees.

An operation was performed on January 31, 1944, under intravenous sodium pentothal. A tourniquet was applied at a pressure of 200 millimeters, and an incision was made along the lateral surface of the right fifth finger at a point between the volar and dorsal nerves and vessels. The lateral surface of the joint was opened through the strong fascial capsule. When this was retracted, it was found that there was no volar capsule. The flexor tendon could be seen running through some areolar tissue. The lateral attachment of

the flexor digitorum sublimis tendon was intact. The capsular structures on the volar surface of the joint were dissected back about four millimeters. The contracted volar ligament, still attached to the proximal part of the middle phalanx, was sutured to the proximal phalanx on the anterior surface. This suture prevented hyperextension of the joint. The lateral capsule was then repaired in such a manner as to shorten the volar side by suturing it more proximally. This prevented complete extension of the joint; it remained flexed about 30 degrees.

The fourth and fifth fingers were then dressed in flexion over a two-inch gauze bandage, and held in place by means of adhesive tape and bandage.

The postoperative diagnosis was posttraumatic dorsal dislocation of the interphalangeal joint of the fifth finger, of a chronic and recurring type.

The postoperative course was good.

February 1, 1944: He was ambulatory, with the right arm in a sling. The hand was comfortable.

February 7, 1944: The sutures were removed. There was no infection.

February 22, 1944: The dressing was removed and an aluminum splint was applied, which held the fifth finger in flexion of 30 degrees at the proximal interphalangeal joint.

February 24, 1944: He returned to partial duty.

April 30, 1944: The following report was received: "I have seen the patient several times and he really has an excellent result. There is extension to about 160 degrees and no limitation of flexion. He is back on flying status and is able to use the throttle quite well. I have suggested that he get a hand-ball to carry in order to strengthen his grip. There is only slight weakness of the fifth finger which should improve with exercise."

May 4, 1944: Another report read: "He resumed his flying duties on March 21. There has been no sign of locking of the fifth finger at the proximal interphalangeal joint and the flyer has been able to resume full duty with respect to flying four-motored planes. The operation is considered very successful. . . ."

NOTE: Through the courtesy of Dr. Samuel Clark, Professor of Anatomy at the Vanderbilt University Medical School, it was possible to dissect a fifth finger in order to work out the details of the anatomy, shown in the drawings by the artist, Miss Susan H. Wilkes.

BILATERAL SYMMETRICAL BRACHYMETACARPALIA AND BRACHYMETATARSALIA

Report of a Case

BY MAJOR FREDERICK J. FISCHER AND CAPTAIN ROBERT E. VANDEMARK

Medical Corps, Army of the United States

Bilateral symmetrical shortening of the fourth metacarpal and of the fourth metatarsal in one individual is an extremely rare anomaly. Boorstein has reported an apparently similar, if not identical, condition in a patient who gave a history of the anomaly in nine other members of her family. The rarity of the anomaly warrants the report of an additional case in which the deformity was not present in any known relative.

CASE REPORT

A private, twenty-six years of age, was admitted to Bruns General Hospital on April 21, 1944, with a transfer diagnosis of (1) bilateral, congenital deformity of the two distal phalanges of the fourth and fifth toes, and (2) hypertrophic arthritis of the ankles. On admission, the patient's chief complaints were (1) pain in the left leg at the site of a varicosity, and (2) pain in both feet on prolonged standing, walking, or drilling. Since early childhood, he had noted that his hands and feet were different from those of other people; his parents knew of no one in the family who had a condition similar to his. In adult life his feet became painful; relief could be afforded only by limitation of activity.

Examination of the feet showed, at first glance, apparent bilateral shortening of the fourth toe (Fig 1); however further examination showed symmetrical shortening of the fourth metatarsals, with plantar calluses under the fourth metatarsal heads. The hands appeared relatively normal with the fingers extended (Fig. 2),

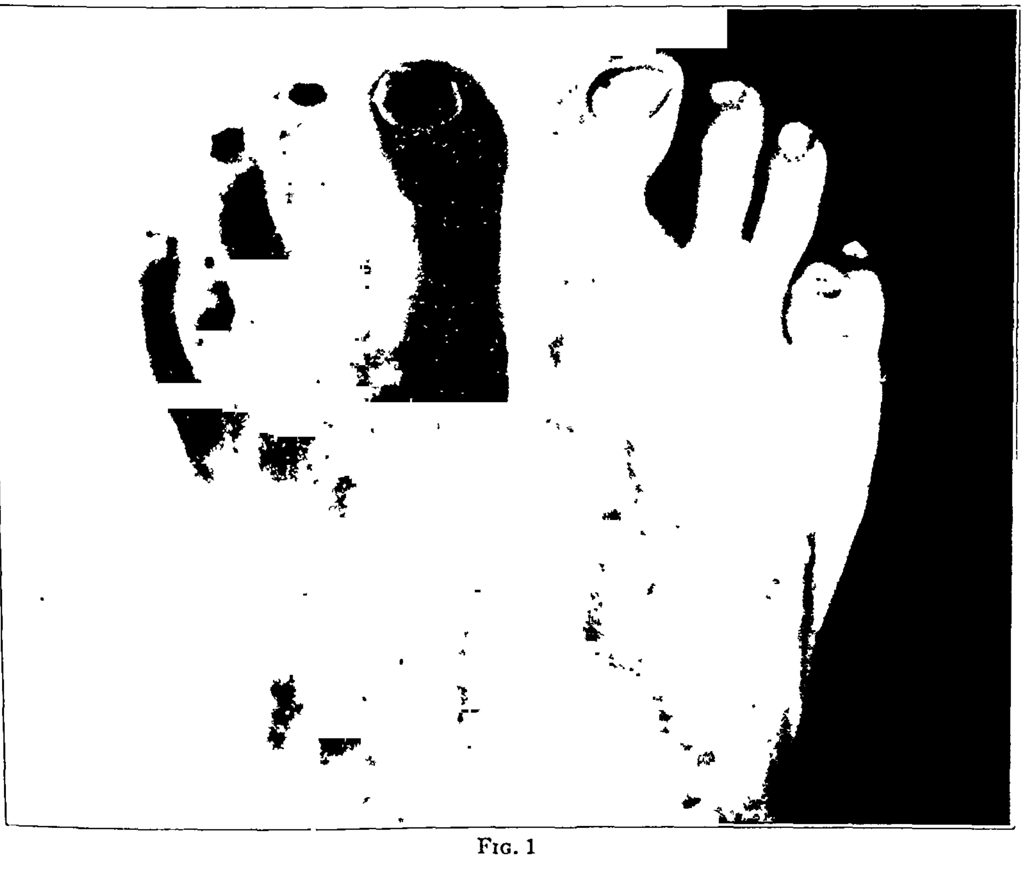

Fig. 1

but flexion of the metacarpophalangeal joints showed symmetrical shortening of the fourth metacarpals (Fig. 3). The condition of the patient's hands caused no complaint. Examination of the ankles was negative.

As an incidental finding, numerous dark brown pigmented areas, varying in size from two to fourteen millimeters, were noted on the trunk and the limbs; some of these areas were elevated above the surrounding skin surface, while others were not. The patient stated that these pigmentations were present in most of the members of his family. Because of the excessive complaints of pain at the site of the mild varix on the lateral aspect of the distal left leg, the patient was seen by a surgical consultant, and later by a neuropsychiatric consultant, who made the diagnosis of a moderately severe hysteria. In view of the latter diagnosis, it was recommended that no surgical treatment of the varix be undertaken, since elaboration and fixation of symptoms might result.

Roentgenographic examination showed bilateral symmetrical shortening of the fourth metatarsal

FIG. 2

FIG. 3

FIG. 4

(Fig. 4), and bilateral symmetrical shortening of the fourth metacarpal, with very slight relative elongation of the phalanges of the ring fingers (Fig. 5). The proximal phalanx of the fourth toe on the left was equal in length to that of the fifth, while on the right it measured slightly less, due to a hyperextended position of the toe. The ankles appeared normal on the anteroposterior and lateral views. Examination of the urine and the blood, including the serological test and the sedimentation rate, revealed no abnormalities.

On the recommendation of the Air Corps Consultant, the patient was discharged from the Hospital to limited duty, with the provision that he be assigned to duties that involved no prolonged standing, walking, or drilling.

DISCUSSION

Previously, congenital shortening of a metacarpal or of a metatarsal has been termed brachydactylia, which is defined as shortening of the fingers or toes. In this case, shortening of the fingers obviously is not present, and that of the toes is more apparent than real (Figs. 4 and 5). For the purpose of accurate description, as suggested by Stecher, the condition is properly called brachymetacarpalia and brachymetatarsalia.

Such anomalies have a hereditary basis. Bagg has clearly shown that they are the recessive to the normal in inheritance. Such recessive characteristics can be transmitted in a family for several generations before reappearance; their presence is forgotten during the interval, as in the present case.

The association of the pigmented areas with this anomaly is of interest. Moore has recently emphasized that the skin pigmentations of neurofibromatosis may be associated with bone abnormalities. Twenty years ago, Esau stated that nervous or neurotrophic causes of shortened metacarpals and metatarsals are not excluded, even in the presence of hereditary factors.

Painful feet was the chief complaint in Boorstein's patient, as in the present patient; this is probably due to the altered mechanics of the metatarsal arch. Cotton and Day

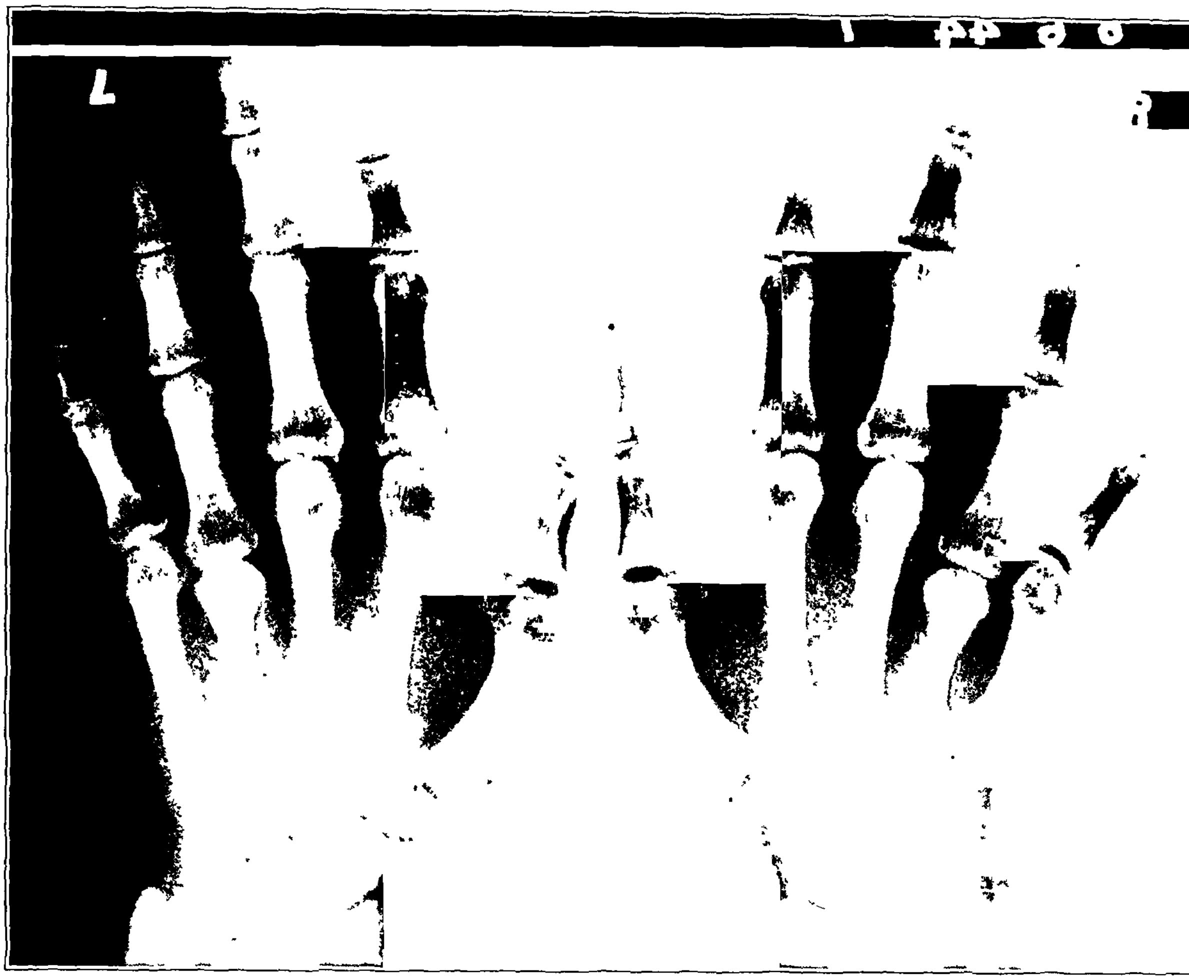

FIG. 5

reported a case of bilateral shortening of the fourth metatarsal, without an associated metacarpal shortening, in which the chief complaint was painful feet. Shortening of the metacarpals causes no complaint, other than that of deformity.

The treatment is symptomatic. Limitation of activity was the only method which afforded relief in the present case. If felt pads or leather metatarsal bars are used, alteration from the usual forms must be made, because of the proximally displaced fourth metatarsal heads.

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MULTIPLE OSTEOCHONDRAL BODIES IN THE SYNOVIAL MEMBRANE OF THE KNEE JOINTS IN A CASE OF MIXED RHEUMATOID AND DEGENERATIVE ARTHRITIS

BY JACOB H. TURKELL, M.D., NEW YORK, N. Y.

From the Bellevue Hospital, New York*

Multiple osteocartilaginous bodies of joints occur in greatest number in osteochondromatosis. They may also be of an articular origin, as detached marginal osteophytes in degenerative arthritis, in neurotrophic joints, in osteochondral fractures of joint surfaces, and in osteochondritis dissecans. The following is a case, diagnosed as mixed rheumatoid and degenerative arthritis, in which multiple osteocartilaginous bodies were found embedded in the synovial membrane of both knees.

CASE REPORT

A. G. (No. 216033), a woman, forty-four years of age, was first admitted to the Hospital in April, 1942. The chief complaint was stiff and painful knees, particularly the right knee. Since the age of twenty-two, she had had repeated episodes of arthritis which involved the joints of her hands, elbows, and knees. Clinical examination revealed fusiform swelling of the proximal interphalangeal joints with ulnar deviation of the fingers at the metacarpophalangeal joints. Motion in both elbows and wrists was considerably limited and was associated with thickening of the periarticular structures. Both knees were moderately swollen and were limited in motion, with discrete nodular thickenings palpable in the suprapatellar pouches. Roentgenogram of the right knee, taken at that time, is reproduced in Figure 1.

The diagnosis of rheumatoid arthritis with multiple loose calcified bodies was made, and a synovectomy of the right knee was performed on May 6, 1942. The findings at the operation were reported in part as follows: "The synovium was replaced by a thick fibrous tissue. Above the articular surface of the femur in the quadriceps pouch were many calcified bodies about the size of marbles and joined together by a fatty-looking fibrous tissue."

The pathological report stated: "The specimen consists of bony particles and fibrous tissue; microscopic sections show an inflammatory reaction of round cells, collected in dense aggregations; many of the vessels are invested with loose fibrous tissue and, in several, lymphoid cells are seen cuffing the vessels. Bone spicules and loose fibrous tissue without inflammatory reaction are seen".

The patient was discharged, considerably improved, in June, 1942.

In October, 1943, she re-entered the Hospital because of disabling pain in the left knee. The improved status since operation in her right knee had remained unchanged. Clinical examination of the patient showed both knees to be moderately swollen and, in the suprapatellar pouch of the left, the discrete nodular thickenings described on her previous admission were palpable. None were felt in the right. Examination of heart, lungs, abdomen, and pelvis was normal. Neurological examination disclosed no abnormal findings.

The laboratory report disclosed the following: the sedimentation rate varied from eight to twelve millimeters per hour; blood calcium, phosphorus, and phosphatase levels were normal; uric acid varied from two to four milligrams per 100 cubic centimeters; blood and spinal-fluid Wassermann reactions were negative; and blood count and urine were normal.

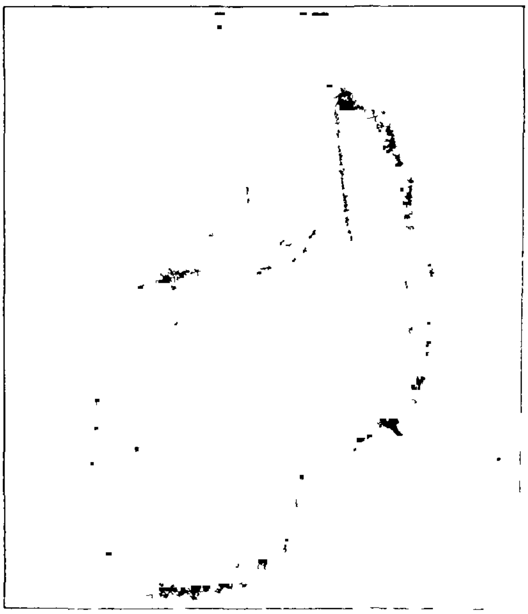

FIG. 1

April 15, 1942. Preoperative roentgenogram of the right knee, showing arthritic changes with multiple loose bodies in the synovial membrane of the joint.

* Orthopaedic Service of Arthur Krida, M.D.

Fig. 2-A

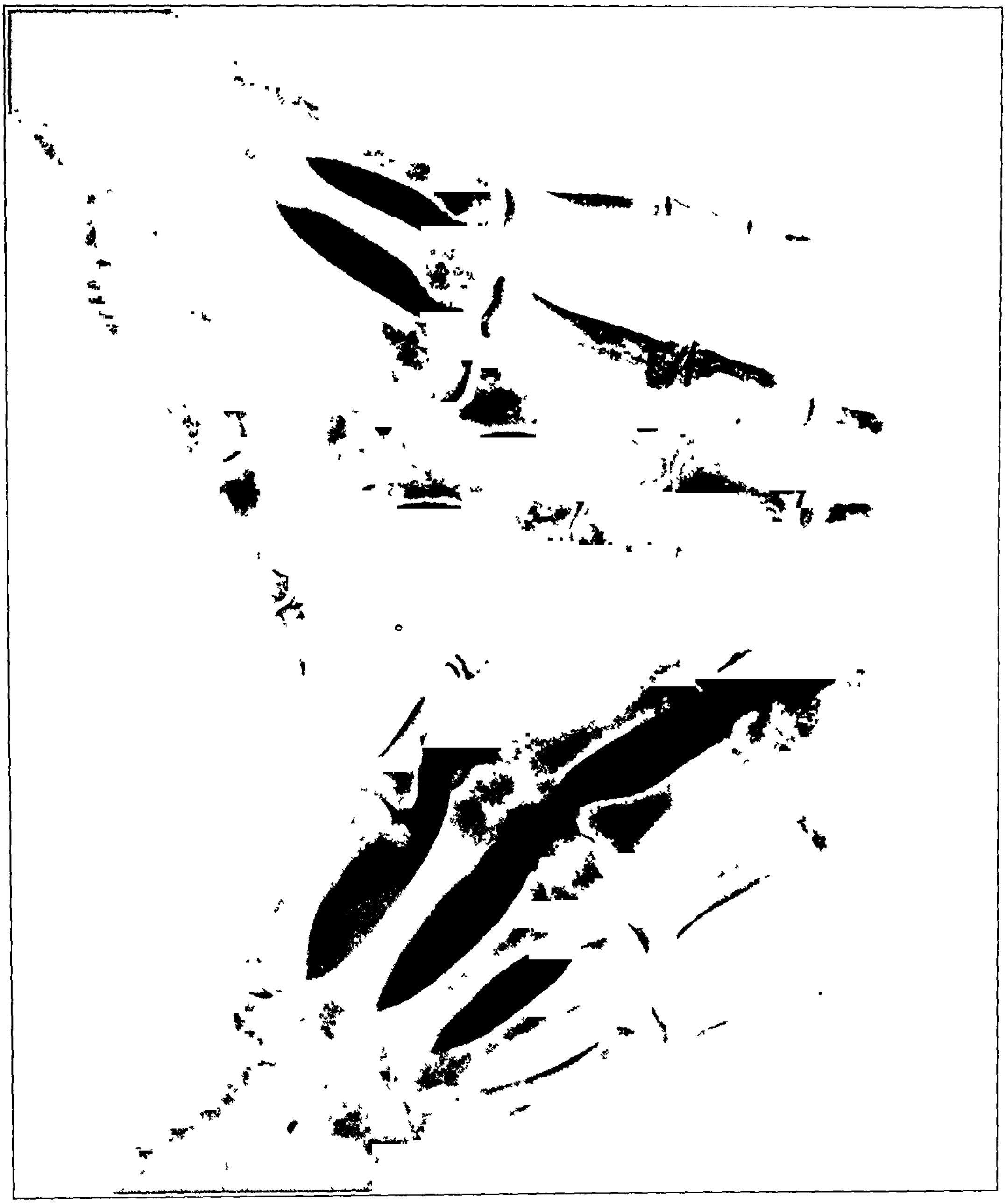

Fig. 2-B

April 15, 1943. Showing the ankylosing process of the elbow and the wrist joints. Destructive changes in the joints of the fingers associated with flexion deformity and ulnar deviation are evident.

On October 27, 1943, a synovectomy of the left knee was performed. The joint was filled with thickened synovia in which were found, in great numbers, calcified bodies, ranging in diameter from one to three centimeters. The consistency of these bodies varied from soft and friable to hard and gritty. The cartilaginous surfaces, particularly of the femoropatellar articulation, showed areas of erosion and hypertrophic changes as evidenced by the formation of peripheral osteophytes. The postoperative course was uneventful.

The pathological report by Dr. Robert J. Poppiti was as follows:

"*Gross Examination:* The gross specimen consisted of numerous irregular masses that varied from one to three and one-half centimeters in diameter. All were either completely or partially enveloped by the thickened, ragged, yellowish-gray synovium. They varied in consistency, being hard in some areas, and soft in others. The masses consisted of material resembling bone, cartilage, and fibrous tissue.

"*Histological Examination:* A section through one of the larger masses shows it to be composed of a central core of well-formed bone with fat between the bony trabeculae. Along the surfaces of some of the trabeculae are prominent osteoblasts. At the peripheral surface, the bone in a few places is covered with cartilage that is undergoing ossification. The mass of bone is surrounded by a capsule of connective tissue of varying density and width; in it are small islands of well-formed cartilage and an occasional small mass of osteoid. Continuous with this capsule is a long strip of fibrocartilage. The capsule surrounding the bone contains large groups of lymphocytes usually in the vicinity of small blood vessels; on the surface is a layer of prominent columnar cells. Section of another mass reveals it to be of essentially the same composition. Attached to this mass are several finger-like projections of fibrous tissue, densely infiltrated with lymphocytes and covered with columnar cells. A third mass is composed of fat and connective tissue; it is moderately vascular and contains scattered aggregates of lymphocytes and plasma cells. Another one of the masses has a center of bone, with fat between the trabeculae. Small islands of cartilage at the periphery of the bone are being calcified and transformed into bone. The surrounding capsule of connective tissue is moderately vascular and contains pockets of lymphocytes near blood vessels. Slender projections of connective tissue extend from the surface; these are the site of chronic inflammatory reaction and are covered with one or more layers of columnar cells." (See Figures 4, 5, and 6.)

The slides of the tissue removed from the right knee (May 6, 1942) were reviewed. No masses of osteoid tissue, similar to that shown in Figure 6, could be found in the slides available for study.

DISCUSSION

The presence of osteochondral bodies in the synovial membrane of both knees to such an extent as to simulate osteochondromatosis is certainly an unusual feature when occurring in joints which are the seat of rheumatoid and degenerative changes.

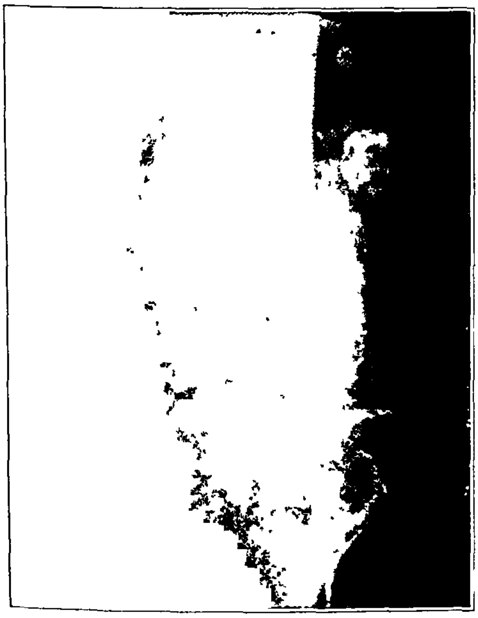

FIG. 3-A

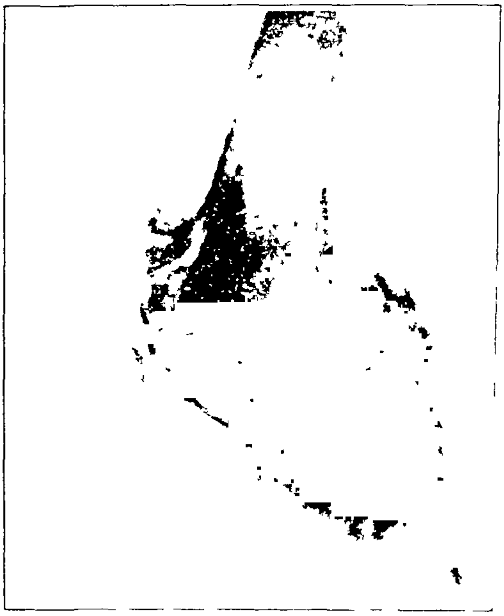

FIG. 3-B

April 15, 1943. Preoperative roentgenograms, showing atrophic arthritic changes of the left knee, with multiple loose bodies of the osteochondromatous type and hypertrophic changes, particularly of the femoropatellar articulation.

Secondary neuropathic derangement superimposed upon a chronic long-standing rheumatoid and degenerative arthritis might conceivably have given rise to the picture presented. This, however, may be ruled out by the absence of abnormal neurological findings and the negative blood and spinal-fluid Wassermann reactions.

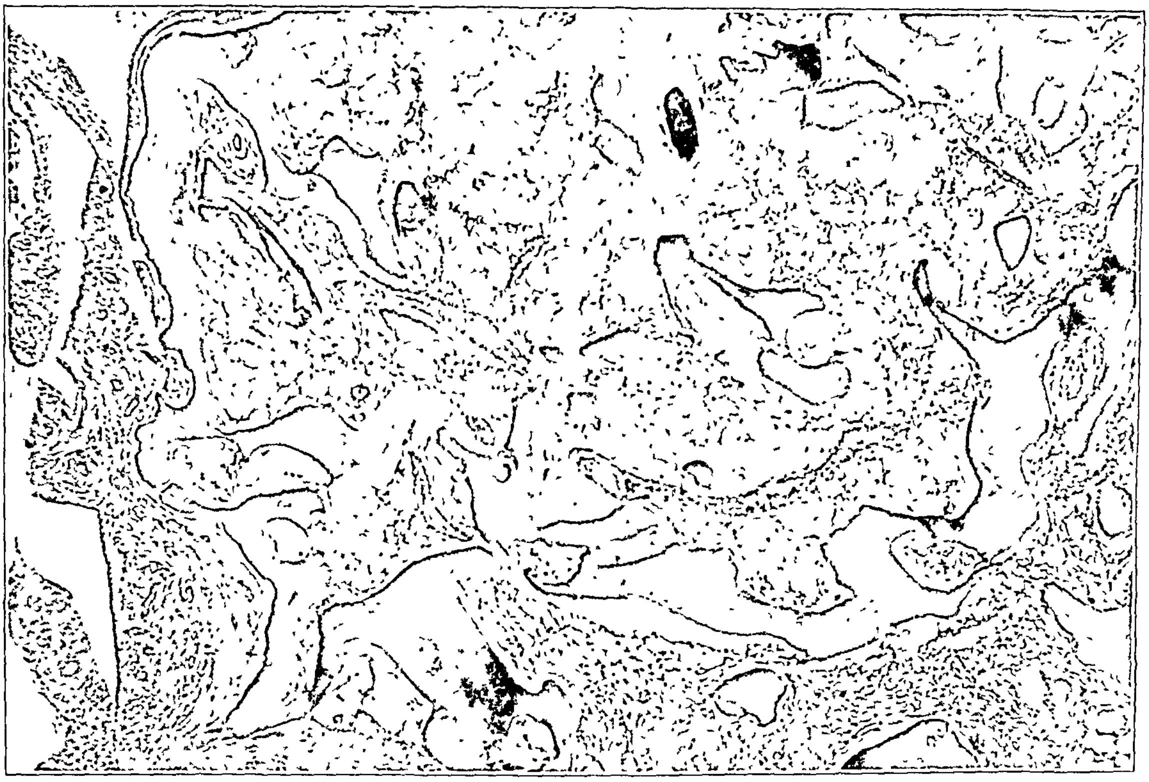

Fig. 4

Photomicrograph (×20), showing an osseous body, containing adult bone spicules with fatty marrow surrounded by chronic granulation tissue, within the synovial membrane.

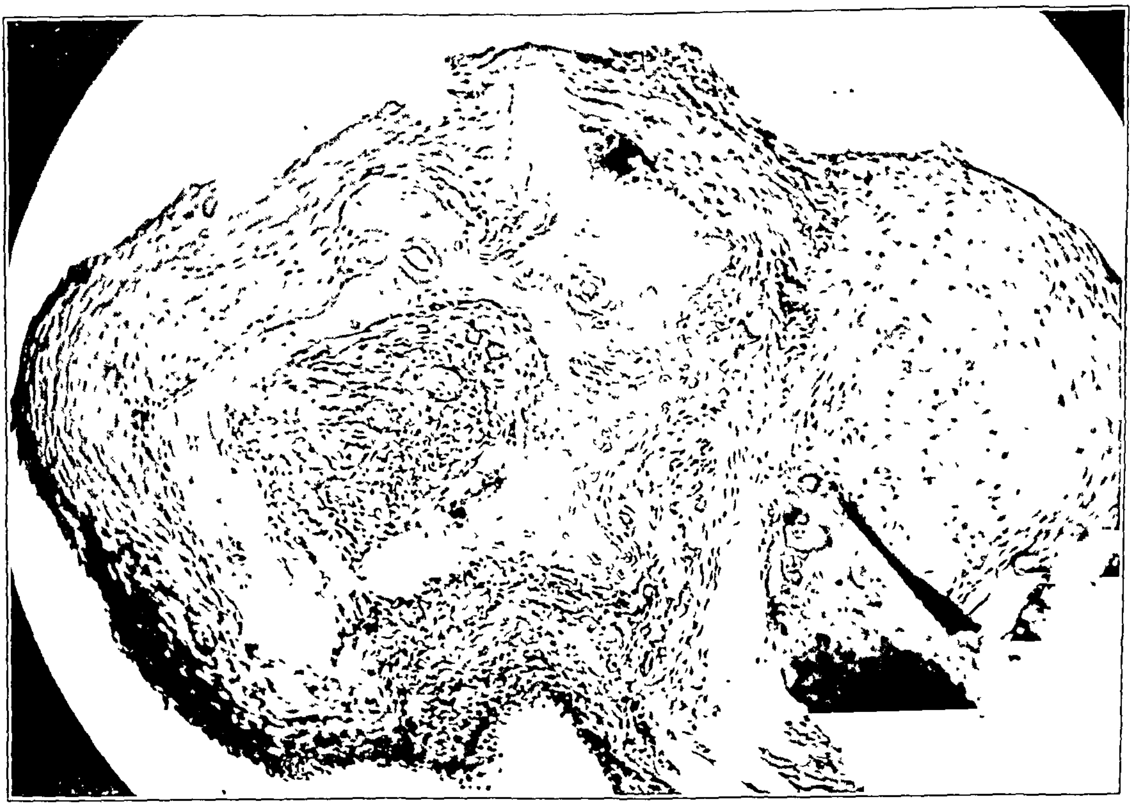

Fig. 5

Photomicrograph (×72), showing an island of well-formed cartilage and bone spicules within a synovial villus. Along the surfaces of the bone, osteoblasts are prominent.

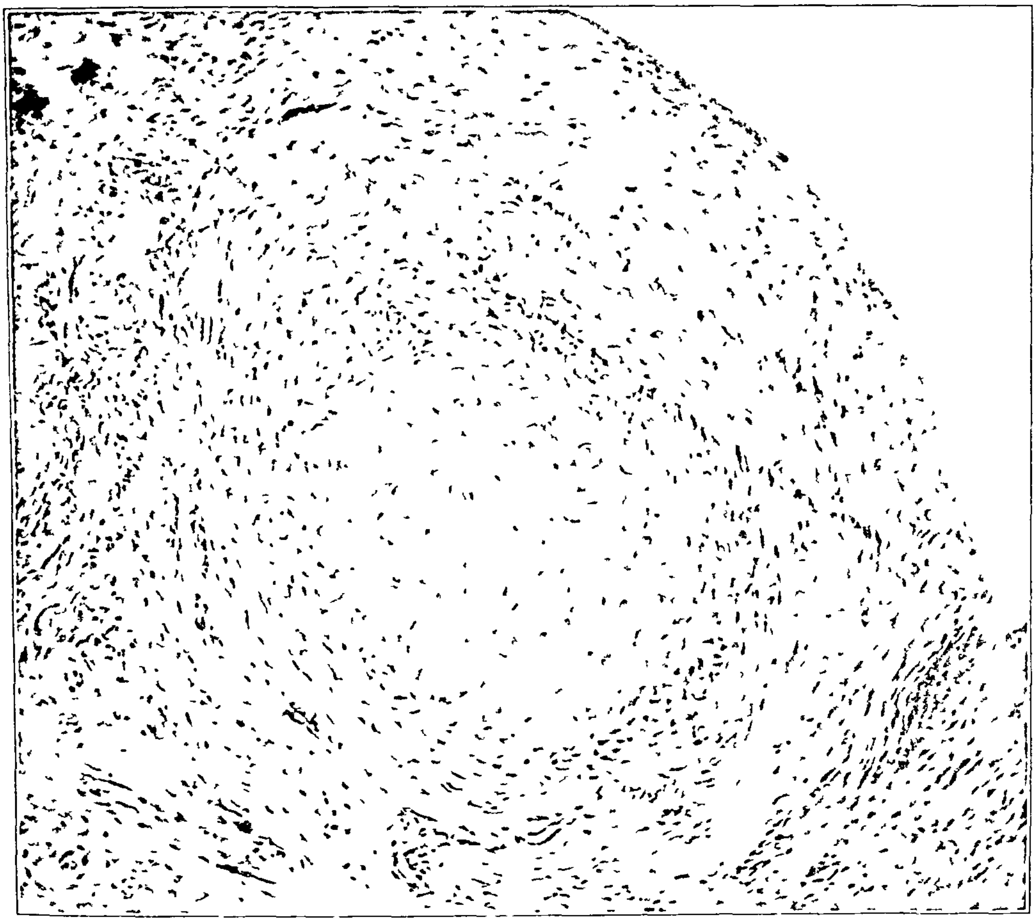

FIG 6

Photomicrograph (×110), showing an area of osteoid tissue in a chronically inflamed synovial villus, indicating osteoid metaplasia of the synovial membrane

That the case may be one of osteochondromatosis in a chronic rheumatoid arthritis might also be considered. Opposed to this are the involvement of both knees, the histological evidence of a chronic synovitis, and the absence of nests of embryonal cartilage cells in various stages of transformation to the more mature type, which would indicate that the changes seen in the synovial membrane are most probably due to an inflammatory, rather than to a neoplastic or developmental process.

It is further conceivable that these bodies arose from peripheral osteophytes which became detached and then secondarily embedded in the synovial membrane. Yet it is difficult on this basis alone to account for the large number of bodies present, the absence of any dead bone or amorphous marrow in the core of at least some of the bodies, and, particularly, the histological evidence of isolated areas suggestive of osseous metaplasia in the villi of the chronically inflamed synovial membrane (Fig. 6).

There is also the possibility that these bodies may have arisen by direct metaplasia of the chronic granulation tissue. The paucity of areas of osseous metaplasia found on histological examination and the failure to note nests of cartilage cells of the more embryonal type, with subsequent maturation and ossification, does not particularly favor such a concept. However, in the chronically inflamed synovial membrane appear areas of osteoid tissue (Fig. 6), together with islands of well-formed cartilage and bone spicules, the surfaces of the latter lined by osteoblasts (Fig. 5).

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A TREATMENT FOR DISPLACED FRACTURES OF THE PELVIS

BY CAPTAIN CAROLL M. SILVER AND MAJOR HAROLD W. RUSBRIDGE

Medical Corps, Army of the United States

Many methods have been employed in the treatment of fractures of the pelvis. In 1935, Jahss reported an ingenious technique which was both simple and effective. The lower extremities were encased in individual long-leg plaster casts, and two turnbuckles were incorporated between them, one, transversely between the thighs, and the other, between the ankle portions of the casts. This created a trapezoid with rigid sides and movable horizontal bars. The lower extremities thus became functional levers. By opening the upper turnbuckle and closing the lower one, a powerful horizontal distracting force could be applied to the pelvis through the medium of the ligaments of the hip joints. Overriding fractures of the ischial and pubic rami, or fractures of the acetabulum with intrapelvic protrusion of the femoral head, could be reduced readily by this method. In the case of a distraction injury of the pelvis, such as a separation of the symphysis pubis, a compression force to effect reduction was applied to the pelvis by closing the upper turnbuckle and opening the lower one.

A patient with an overriding unilateral fracture of the pubic and ischial rami was admitted to a station hospital in North Africa, and it was planned to treat the pelvic fractures by the Jahss method. Since turnbuckles were unobtainable, a simple substitute was necessary. This case report is presented as a practical suggestion for the treatment of pelvic fractures, and may be of particular use in military hospitals overseas where non-standard equipment must often be improvised or a substitute found.

CASE REPORT

J. T., a Navy lieutenant, thirty-six years of age, was admitted to a station hospital in North Africa, April 16, 1943, shortly after he had been thrown from a jeep which overturned while in motion. The patient was in moderate shock, and an intravenous infusion of 1000 cubic centimeters of plasma was begun at once. Examination revealed a severe laceration of the right scrotal sac, with protrusion of the right testicle through

the wound. Marked tenderness over the left pubic and ischial rami was found, and lateral compression of the pelvis caused severe pain in this region. A tentative diagnosis of fracture of the pelvis was made. The patient was catheterized soon after admission; clear yellow urine was obtained. Several hours later, a roentgenogram of the pelvis was made, which revealed fractures of the left superior pubic and ischial rami with moderate overriding of the fragments (Fig. 1). Padded plaster-of-Paris circular casings were applied to each lower extremity from the upper thigh to the ankle, with the knees in full extension. A pad of felt, three-quarters of an inch in thickness, was applied about the upper thighs, the knees, and the ankles before the legs were encased in plaster. The scrotal laceration was cleaned thoroughly with normal saline, the testicle was replaced in the scrotal sac, sulfanilamide powder was sprinkled into the scrotum, and the laceration was repaired with interrupted black-silk sutures. Two days later, when the casts were dry and firm, the patient was placed on the x-ray table in the supine position. He had been given a quarter of a grain of morphine half an hour earlier. A wood block, six inches wide and two inches thick, was placed transversely between the upper-thigh portions of the plaster cylinders, and a webbed canvas strap with a buckle was placed around the

Fig. 1

Prereduction roentgenogram showing overriding fractures of the left pubic and ischial rami.

Fig. 2

The block of wood and the webbed strap are in position. The patient is lying on the x-ray table.

Fig. 3

The wood block and the strap have been incorporated in plaster-of-Paris following reduction, to ensure fixation of the reduced fragments.

Fig. 4

Postreduction roentgenogram. There is normal alignment of the left pubic and ischial rami.

ankles (Fig. 2). The webbed strap was tightened, producing a horizontal distraction force on the pelvis by levering the lower extremities over the block fulcrum. When the patient complained of moderate pain at the fracture site, the tightening of the strap was stopped, and a roentgenogram of the pelvis was made. The postreduction roentgenogram showed complete correction of the overriding with normal alignment of the fracture fragments. The wood block and webbed strap were incorporated in the plaster-of-Paris casts to ensure fixation of the reduced fragments (Fig. 3), and the patient was returned to the ward.

It had been almost impossible to place the patient on a bedpan, because of the severe pain prior to the final fixation of the plaster casts. Following immobilization in the casts, the patient could be lifted on a bedpan or could be turned with ease, and he was able to sit up in bed or in a wheelchair without difficulty. A roentgenogram taken several days later showed no change in the anatomical alignment at the fracture sites (Fig. 4). The scrotal wound healed *per primam* and the sutures were removed after one week. On April 28, 1943 the patient was transferred to a Naval Dispensary in accordance with orders from Headquarters and no further record has been obtained regarding the case. At the time of transfer, the officer was quite comfortable and was out of bed daily in a wheelchair.

COMMENT

The materials required for reduction and immobilization of pelvic fractures are few and easily obtainable. They include plaster-of-Paris, sheet wadding, felt, a block of wood, and a webbed strap or ordinary trousers belt. For a distraction fracture or pubic symphysis separation, the block of wood and webbed strap are simply reversed. Morphine sedation was adequate in this instance for the reduction procedure. The obturator muscles and pelvic ligaments act as automatic aids to check the possibility of overdistraction in the reduction of overriding fractures. In a second article in 1939, Jahss advised the use of two turnbuckles between the thighs to prevent external rotation of the limbs. The authors made no special attempt to prevent the external rotation of the lower extremities, since the transverse distracting force was not affected. In fact, a slight amount of external rotation is desirable, since it reduces the amount of direct stress on the lateral ligaments of the knee, caused by the leverage action of the reduction mechanism.

The patient is surprisingly comfortable in the retention casts after the initial postoperative reaction, and he can be turned over or propped up in bed; he can be placed on a bedpan, or can be put in a wheelchair. Of great importance in wartime is the fact that the patient can be transported with safety to a base hospital or other rear echelon installation. Associated wounds of the pelvic region can be treated with ease, since only the lower extremities are enclosed in the casts.

If the pelvic fracture is complicated by displacement in the vertical axis, the incorporation of a Roger Anderson well-leg apparatus in the casts for vertical traction, as reported by Jewett, would be advisable.

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RAPID ROENTGENOGRAPHY IN THE OPERATING ROOM

BY W. L. MINEAR, M.D., PH.D., MEMPHIS, TENNESSEE

From the Willis C. Campbell Clinic, Memphis

The purpose of rapid roentgenography in the operating room is to save anaesthetic time, especially in patients who are poor risks, and to facilitate the developing of roentgenograms in hospitals where the dark room is remotely or inconveniently placed. The problem of rapid roentgenography has been discussed by Ollerenshaw, who used a special single-solution developer in a portable box. The formula was unique in that it contained hypo mixed with developer in a highly alkaline solution, and fixation proceeded at the same time as development. This caused a tendency to reduce film density, and it was, therefore, necessary to double the normal exposure time. The chemicals were mixed immediately before being used, and, because of instability, were discarded after one use. The solution was contained in a developing tray, placed in the bottom of the portable box. The cassette was unloaded in the light-tight box, and the film was developed for forty-five seconds, when it was ready for inspection by the surgeon. The film was then immersed in hypo, as in the standard procedure when permanent films are desired. F. R. Wilkinson modified Ollerenshaw's solution and discussed its use.

Our experience with the single-solution developer revealed its advantages of speed and simplicity. Its disadvantages were a low-density film with yellow discoloration (fog), and non-diagnostic lateral hip films in heavy subjects. The solution is unstable, can be used only once, and costs approximately fifty cents per 1000 cubic centimeters.

It was found that the quality of the films could be improved to some extent, with less fog, if the films were immersed in hypo for five to ten seconds after developing. The roentgenograms of extremities and hips in thin subjects were considered diagnostic, and were of fair quality; however, continued difficulty was experienced in visualizing the head and neck of the femur in the lateral exposure in heavy subjects (curved cassettes were used). Because of these difficulties, the single-solution developer was discarded in favor of a fast, concentrated, commercial liquid developer* which was used warm or at room temperature, with the standard procedure of successive immersion in developer, wash water, and hypo. This procedure was carried out in a light-tight portable box in which was installed a standard dental tank, large enough to hold films eight by ten inches in size. Films are developed one minute, at 85 degrees Fahrenheit, are rinsed, and are placed in hypo for thirty seconds. It was found that one and one-half to two minutes for the whole procedure was rapid enough for all practical purposes, and films of good quality were obtained. The time-temperature factors for fresh developer are: one and three-quarters minutes at 75 degrees Fahrenheit, one and one-quarter minutes at 80 degrees Fahrenheit, one minute at 85 degrees Fahrenheit, and forty-five seconds at 95 degrees Fahrenheit. About forty-five films, eight by ten inches, may be developed in three-fourths of a gallon of developer before any lessening of film density will be noticed. The rate of oxidation of developer doubles for each 10-degree rise in temperature over 65 degrees Fahrenheit. The higher the concentration of developer, the more rapid is the oxidation.

The developing solution can be warmed to the desired temperature immediately before it is used, or it may be kept at a constant temperature while in use by a special thermostatically controlled heating unit immersed in the developing solution. Construction of the portable box, placement of the cassette and tank, and the nature of the film holders are illustrated in Figures 1 and 2.

* The time factors mentioned are based on the use of "Supermix developer" and "hypo" (General Electric), used in dilution recommended.

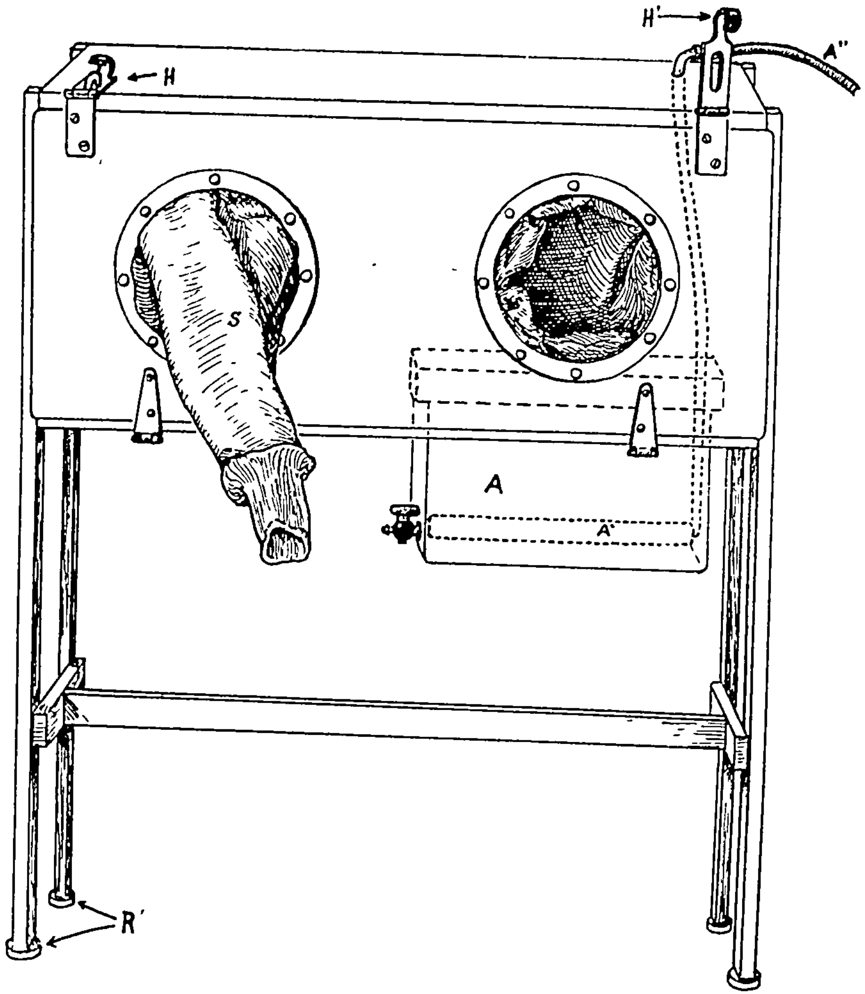

Fig. 1

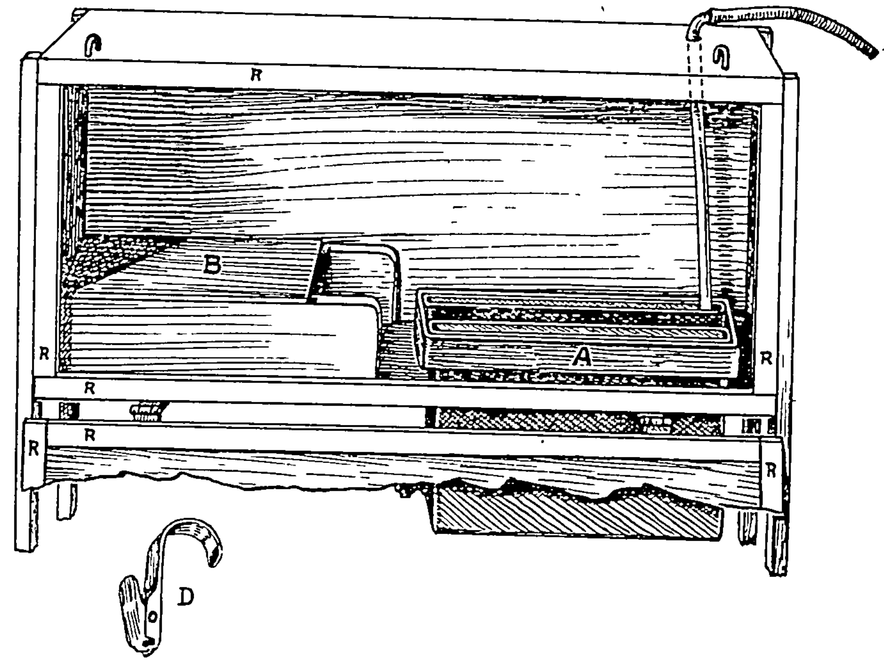

Fig. 2

Figs. 1 and 2: The portable box, of plywood, is made with light-tight seams. Inside dimensions are: thirty inches in length, fifteen inches in height, and twelve inches in width. The door has two armholes, eight inches in diameter and four inches apart, with attached rubber-sheeting sleeves (*S*) (everted on left, Fig. 1), and stockinette cuffs (four thicknesses). The sleeves are attached by means of stove bolts with plywood rings and felt gaskets. The opposing edges of the door and box have sponge-rubber strips, one inch wide and a quarter of an inch thick. The door is attached with hinges and is secured when closed with a common latch (*H* and *H'*). The box is supported by legs twenty-six inches high, so that the technician may conveniently sit down while developing films. Rubber tips (*R'*) are placed on the legs to prevent slipping of the box on the floor. The interior of the box has a small elevated cassette platform (*B*) on the left. The area under the cassette platform is lined with lead foil, one millimeter in thickness, and is used for storing films. A standard dental tank (*A*) (7¼ by 13¼ by 9¾ inches, outside diameter) is shown on the right. A thin rubber strip around the opening in the bottom of the box makes the tank installation light-proof. Placement of the thermostatically controlled heating unit (*A'*), in the rear compartment containing developer, and of the cord (*A''*) leading to current of 110 volts is shown. The stopcock at the bottom of the tank drains the wash water after each use. A constant flow of wash water is optional. The developing and hypo tanks may be removed for change of solutions. Dental clip for holding film is shown in Figure 2 (*D*).

The portable dark room should be conveniently placed near the x-ray view box in the operating room. The temperature of the warm developing solution should be measured, and the developing time should be predetermined by reference to the time-temperature table. Roentgenograms are taken with the portable x-ray unit; the operator follows standard technique for the part. The developing time need not be increased, but this is left to the discretion of the technician. Our technique for lateral hip roentgenograms involves the use of a curved cassette placed between the legs. The anteroposterior view is taken with a flat cassette with attached Siemen's grid, and is placed in an x-ray tunnel centered under the patient's hips. The curved cassette is placed on top of the flat cassette on the left side of the box. The lid is closed, and the technician inserts his hands and arms in the light-proof sleeves attached to the portholes; both hands are used to unload the curved cassette. The film is held with the left hand, and the film holder, which is kept in the box, is grasped in the right hand; the film is then attached. The film is placed in the developing solution in the back compartment of the tank. This procedure is repeated for the anteroposterior film in the flat cassette. The two films remain in the developer for the proper length of time (for example, one minute at a temperature of 85 degrees Fahrenheit), are rinsed briefly in water in the center tank, and then are placed in hypo contained in the front compartment. The technician now may withdraw his hands and open the lid of the box. Ideally the films should be left in the hypo as long as the developing time, but they may be withdrawn from the box in thirty seconds and placed on the view box for inspection. If permanent films are desired, they should be reimmersed in hypo, and washed and dried in the usual manner.

The cassettes may be loaded in the box as follows: A box of film, eight by ten inches, is placed flat on the cassette platform (Fig. 2, *B*), so that the lid may be removed toward the right. The unlocked flat cassette opening to the right is placed on the box of film, and the unlocked curved cassette, in turn, is placed on the flat cassette. The portable box is now closed, and the technician inserts his arms in the sleeves. The lid from the film box is removed and is placed under the cassette platform. Cassettes are opened individually with the left hand, and the film is inserted with the right hand. Cassettes are then locked, using both hands, and the lid to the film box is replaced. Films are stored under the cassette platform between loadings.

The solutions are stable, and can be kept in the tank or stored in gallon bottles. Wash water should be drained after each use. The tank can be easily lifted out of the box, or the developing and hypo compartments within the tank may be lifted out separately and cleaned.

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A CASE OF CYST OF THE SACRUM WITH NO INCREASE AFTER THIRTY YEARS

BY JOEL E. GOLDTHWAIT, M.D., BOSTON, MASSACHUSETTS

On March 18, 1920, a case was reported in the *Boston Medical and Surgical Journal*, entitled "A Case of Tumor of the Sacrum". This report is now given, since it seems of distinct value to know something of what happens in these cases.

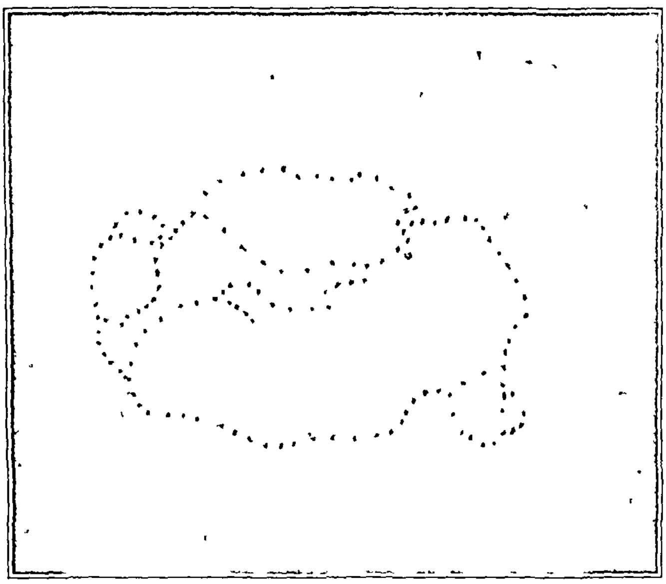

FIG. 1

Reproduced from Boston Medical and Surgical Journal by courtesy of The New England Journal of Medicine.

At the time the case was first reported, the patient, a woman, was forty-four years of age. She had been referred to me in November 1909 by Dr. Maurice H. Richardson, who sent the following letter:

"She was operated upon by a friend of mine, Dr. Giles, of Hanover, N. H. Dr. Giles some years ago did a ventral fixation. It was thought at that time that she had some malignant disease of the liver. I studied her case carefully and then operated, finding that the ventral fixation had become separated and that there were gall-stones. I removed the gall-stones and fixed up the uterus. In the hollow of the sacrum there was a mass which I supposed to be inflammatory before operation. Inside the abdomen I found a firm mass connected with the sacrum, sessile, broad, and evidently containing fluid. We thought at the time that this might be due to caries of the sacrum. She has

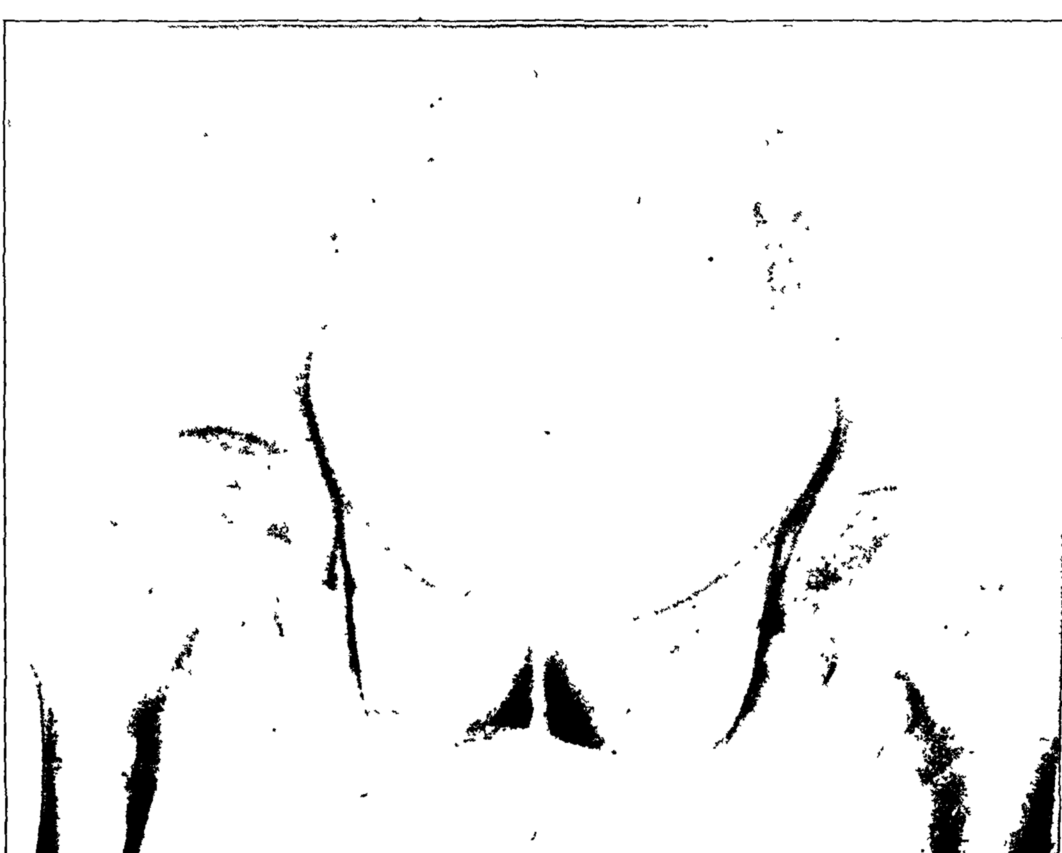

FIG. 2
January 19, 1933.

Fig. 3
June 2, 1944.

done very well indeed since the operation. She is the picture of health. The mass in the hollow of the sacrum is distinctly smaller, but on the posterior surface of the sacrum there is, as you will see, a prominence which confirms the diagnosis of caries of a benign origin."

At the time of the examination, there was a marked prominence of the upper part of the sacrum, giving the impression at first of a distinct spondylolisthesis; but, on more careful investigation, it was evident that the whole spine had not been displaced forward, as it is in spondylolisthesis, but that much of the appearance suggestive of this condition was due to the swelling over the sacrum, associated with a considerable forward inclination of the pelvis. The roentgenogram taken at that time (Fig. 1) showed an almost complete destruction of the sacrum; only a shell remained around the outer edges, so that there could not have been more than one-half of an inch of bony structure in contact with the ilia. The same was true of the upper part of the sacrum, upon which the spine would naturally rest.

The condition was so extensive that operative treatment was considered inadvisable, and a support was arranged to protect the pelvis and the low back. The patient was relieved of the discomfort, for which treatment was sought, and, for many years, has been an active person, carrying on a drug-store business of her own.

Since the report presented previously, the patient has been seen by me occasionally. After a somewhat longer interval she was seen again. At that time, she had given up her business, but was doing her housework, moving about a moderate amount, having very little pain, and being in remarkably good condition for her age, which was seventy-nine years. The roentgenograms which were taken at that time (Fig. 3) showed a condition almost exactly like that which was shown at the time of the first examination in 1909.

The case, of course, represents a cyst of the sacrum, with marked destruction of the main part of the bone, which has remained for many years entirely inactive.

MARCH FRACTURE OF THE NECK OF THE FEMUR

A Case Report

BY MAJOR MURRAY E. GIBBENS

Medical Corps, Army of the United States

In view of the present interest in march ("insufficiency", "fatigue") fractures, the author submits herewith a report of a case of march fracture of the neck of the femur, similar to those reported by Branch, Mullard, and Watson and Berkman.

The patient, a white male, thirty-eight years old, was brought to the Orthopaedic Section of the Station Hospital, Camp Barkeley, Texas, on January 7, 1943. He was a man of rather asthenic build, and prior to induction he had been a dentist. He had experienced sudden, severe pain in his right hip during a twenty-five mile march, and was unable to bear weight on his right leg. There was no history of injury or unusual strain, other than that of walking. He had not fallen, and he could not recall having stumbled or having turned his ankle. He had had no similar attacks of pain previously. There was some muscle spasm on rotation of the right hip; otherwise there was no limitation of motion except upon sudden extension. The diagnosis on admission was acute arthritis of the right hip.

Roentgenographic examination

A series of roentgenograms was taken, and the final diagnosis of march fracture of the neck of the femur was made.

The first x-ray (January 8, 1943) yielded "negative" findings. However, on minute scrutiny, it was subsequently found that there was a break in the continuity of the cortical surface of the inferior margin of the femoral neck (Fig. 1), which appeared as a very small, oblique, linear defect in the cortex. No similar break could be found in the superior margin of the neck.

On January 29, 1943, the second roentgenogram was taken, and the following report was made: "There is definite evidence of a fracture through the neck of the right femur, with discontinuity of the cortical borders in each side, and a line of decreased density extending across the neck, bordered by an increase in density on each side. The line of the neck and head of the femur has not been altered. We believe this is a march fracture of the neck of the right femur".

A third x-ray, under date of February 20, 1943 (Fig. 2), showed that, "There is now some bone condensation about the previously described fracture line across the neck of the right femur".

The report after roentgenographic examination on April 5, 1943, stated: "There is obliteration of the previously reported fracture line, with visible callus on the medial side of the neck of the right femur".

Treatment consisted of bed rest, with motion allowed in bed. On January 14, exercises in bed were started, and the patient was permitted to be up on crutches for short periods of time, without weight-bearing on the right leg. A week later, he had good, active motion in the right hip. Weight-bearing was not allowed until one month after admission, at which time he began to walk with a cane.

On March 12, 1943, the patient was placed on temporary "limited service" status for a period of six months. This was chiefly because of his age and the type of injury.

This soldier returned to duty from the Hospital on March 19, 1943, and was able to complete his basic training without difficulty.

Follow-up examination was made at the Orthopaedic Clinic on May 5, 1943. A roentgenogram taken at that time (Fig. 3) showed good healing, with a moderate amount of callus at the fracture site. The hip joint functioned normally, and the patient walked without difficulty.

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Fig. 1

January 8, 1943. The lower arrow indicates the site of the break in the continuity of the cortex on the inferior surface.

Fig. 2

February 20, 1943. Between the two arrows is the area of bone condensation.

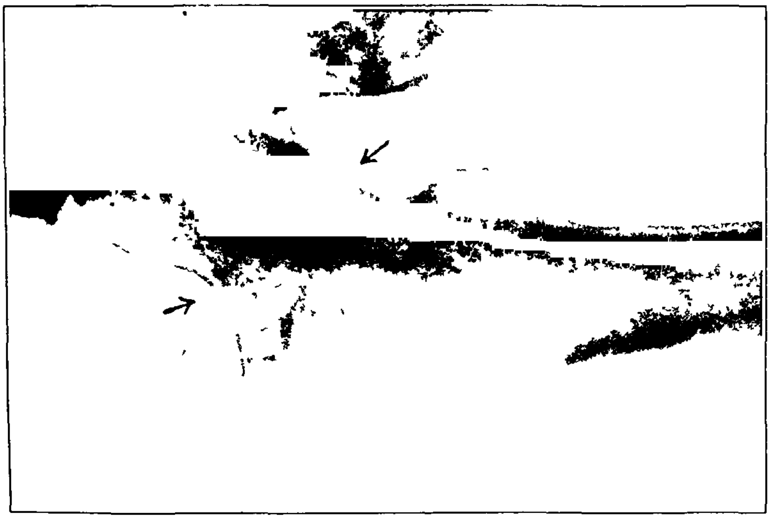

Fig. 3

May 5, 1943. Increased density is visible at the fracture site, with callus at the medial side of the femoral neck.

BILATERAL CONGENITAL CALCANEOCUBOID SYNOSTOSIS

A Case Report

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Medical Corps, Army of the United States

From the Orthopaedic Service, A.A.F. Regional Station Hospital, Truax Field, Madison, Wisconsin

Congenital synostosis of the tarsal bones appears to be a rare deformity, since only few cases have been reported in the literature. Congenital fusion of the calcaneocuboi joint in the foot, without either synostosis or absence of other tarsal or metatarsal bone has been reported by Wagoner, and Bargellini. Wagoner's patient was a boy, nine yea of age, who had pain in both feet on arising, with relief following exercise. Lapidus r viewed the literature on congenital fusion of the foot bones and described a case of tal navicular synostosis. O'Donoghue and Sell have reported another case of congenit talonavicular synostosis.

The tarsal cartilages appear in the embryo of about fourteen millimeters, and th joint cavities develop in the embryo twenty-five to thirty millimeters long. It is at th later period, when the foetus is approximately two months old, that there is a failure (the joint cavity to develop, and the two bones grow as one.

CASE REPORT

A white male, thirty-five years of age, was seen in the Orthopaedic Clinic of the Station Hospital, Trua Field, with the complaint of back pain. He had sustained a fracture of the right lateral malleolus four yea previously, and had felt pain on walking on the right foot since that time. There were no complaints refe able to the left foot. Examination of the feet showed bilateral pes planus of 2 degrees. Dorsiflexion wa limited, as were eversion and inversion of both feet. A roentgenogram of the right foot was ordered, an when structural changes were found, one of the left foot was taken for comparison.

The roentgenogram of the right foot (Fig. 1-A) showed no joint space between the calcaneus and th cuboid. These bones appeared otherwise normal. The subtalar joint was normal. On the posterior su face of the talus was a mass of bone which measured one by one centimeters. A mass of similar size an appearance was present on the anterior superior surface, just posterior to the talonavicular joint. Th roentgenogram of the left foot (Fig. 1-B) showed it to be similar to the right, except that there were hype trophic changes at the cuneonavicular articulation. Since there was no history of severe trauma or infectio in either foot, and the identical lesion was found bilaterally, a diagnosis of bilateral congenital calcaneocuboi synostosis was made.

DISCUSSION

As motion in the calcaneocuboid joint is prohibited in this condition, there is a strai on the other intertarsal joints, and an anomaly of this type is likely to be symptomatic The hypertrophic changes in the left foot in this case are probably the result of this strain As a therapeutic measure, a subtalar and talonavicular arthrodesis might prevent such strain on the other intertarsal joints and relieve symptoms. This was not attempted i this case because of military policy.

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Fig. 1-A
Roentgenogram of the right foot, showing calcaneocuboid synostosis.

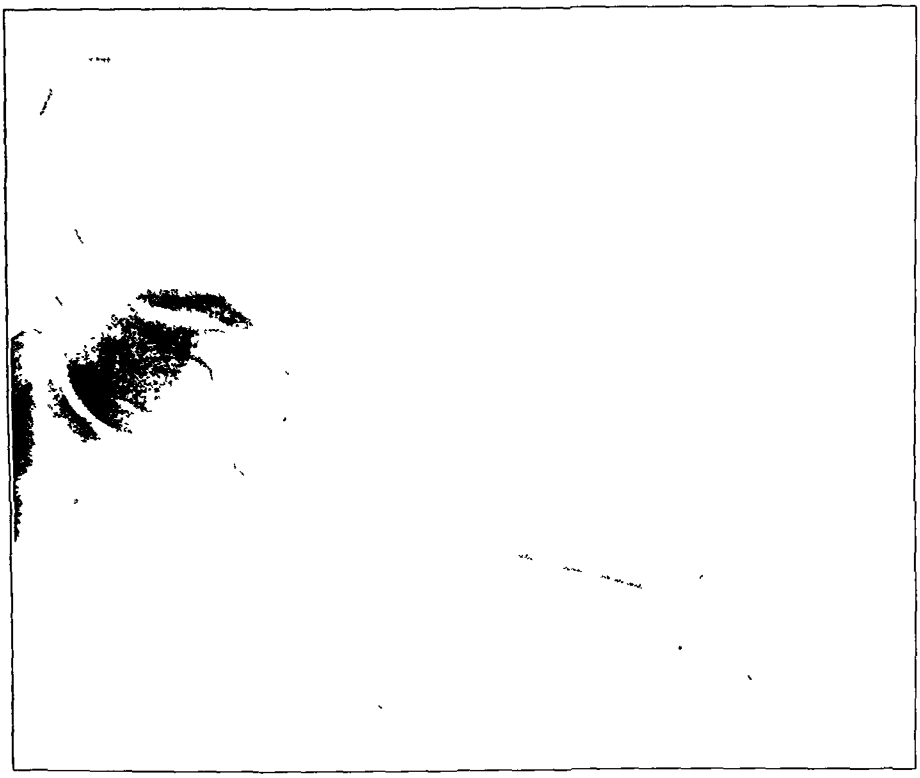

Fig. 1-B
Roentgenogram of the left foot, showing calcaneocuboid synostosis.

V PLASTER SPLINT FOR MAINTAINING REDUCTION OF CONGENITAL DISLOCATION OF THE HIP

BY R. PLATO SCHWARTZ, M.D., ROCHESTER, NEW YORK

The purpose of this brief illustrated report is to reveal the advantages of departure from the conventional plaster spica for immobilization of congenital dislocation of the hip.

On March 29, 1944, when the patient, (J. F.) was two years of age, a closed reduction of bilateral congenital dislocation of the hip was performed, with fixation in a conventional plaster spica.

On April 14, 1944, the patient was discharged to her home.

On April 26, 1944, she was readmitted, because the spica was saturated with urine, and there was cutaneous inflammation over the pelvic area and the proximal third of both thighs. The inflammation cleared up within two weeks following the removal of the spica. Recurrence of bilateral dislocation (Fig. 1-A) made a second reduction necessary.

On May 9, 1944, closed reduction of both hips was again done; fixation was obtained by a V plaster splint (Figs. 2-A and 2-B). Roentgenograms showed that the reduction had been maintained (Fig. 1-B) by this V splint when patient was sitting up (Fig. 1-C).

On August 18, 1944, the patient was readmitted. The plaster was unsoiled, but tight from increased growth of the patient. New plaster was applied without anaesthesia (Fig. 1-D).

The roentgenograms indicate that reduction of both hips has been maintained in two successive V plasters. It is now nearly six months since the first one was applied to this patient. During that time, the patient has been free to sit up, and the reduction has remained unchanged.

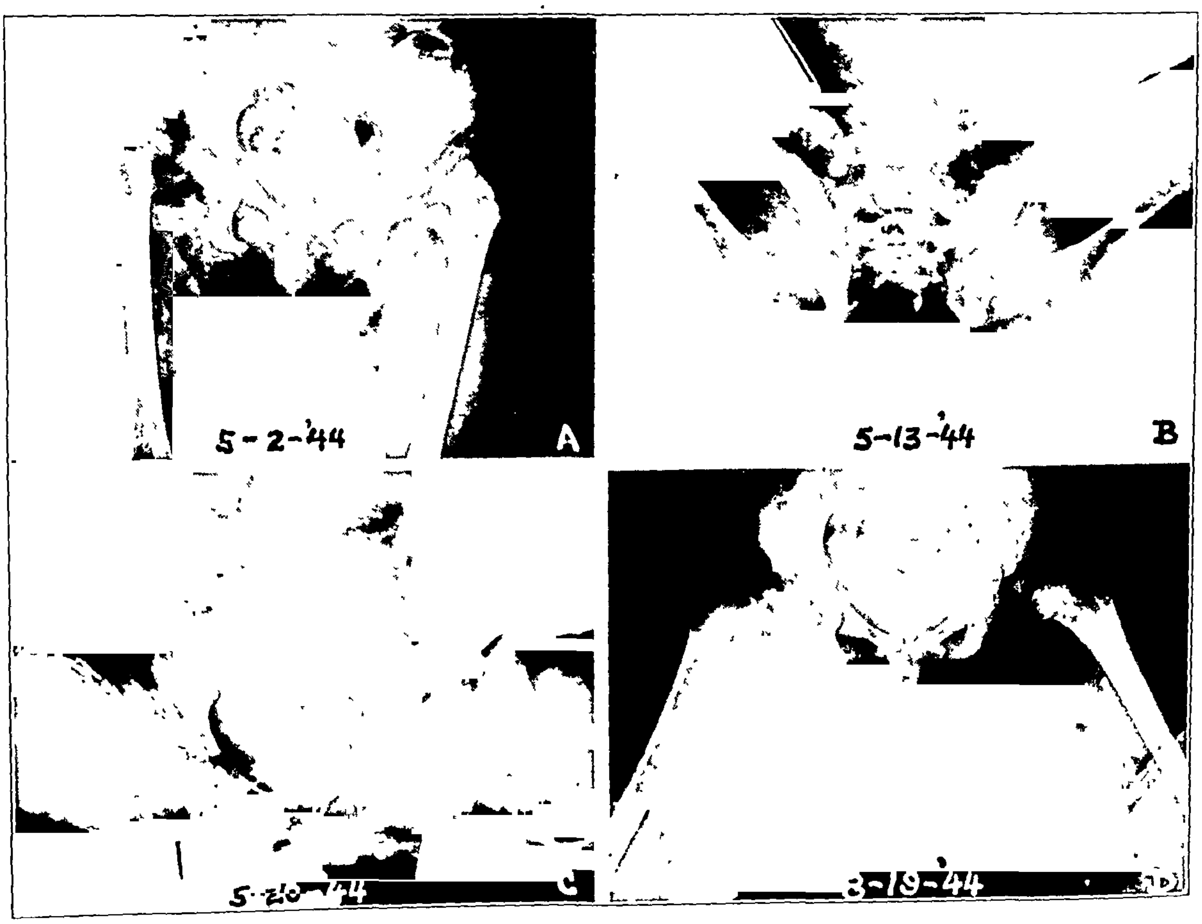

FIG. 1

A. Bilateral dislocation before reduction.
B. Closed reduction maintained by V plaster splint.
C. Reduction maintained, patient sitting up (Compare with Fig. 2-A).
D. Reduction maintained by second V plaster splint (Note the difference in the acetabula by comparing *A* and *D*).

The extension drill with sleeve is very simple in construction, and can be made at little cost. A piece of drill rod, or other suitable steel rod, twenty-one centimeters (9 inches) long, is brazed onto an ordinary drill point of the desired size (Fig. 1). The extension should be slightly smaller than the drill point. Brazing is preferred to welding, because the bond which it produces is less apt to fracture. The joint is made smooth and of the same size as the extension rod.

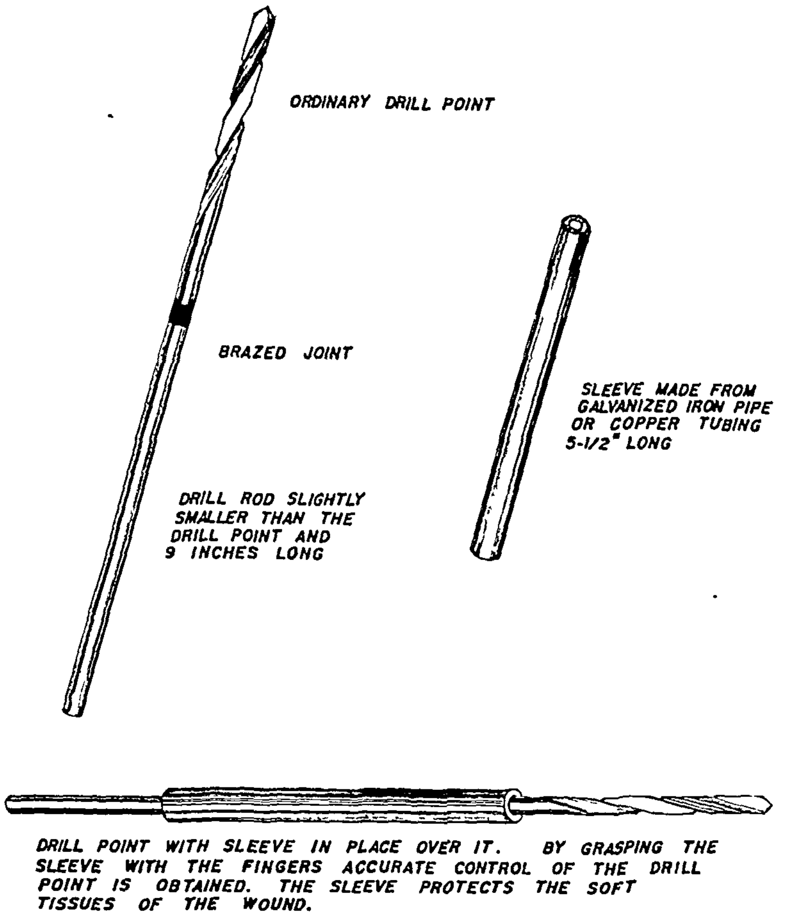

FIG. 1

The sleeve for the larger sizes of drill points is made from a piece of galvanized cast-iron pipe, 13.75 centimeters (5½ inches) long, with a bore 0.3 of a centimeter (⅛ of an inch) in diameter. Copper tubing is used for smaller drill points. The ends of the sleeve are carefully reamed out to the full size of the pipe or tubing, and they are smoothed with a file or emery cloth. A close fit between the drill point and the sleeve is not desirable; a quite loose fit works well, and makes it possible to use one sleeve for several sizes of drill points.

In drilling holes nearly parallel with the axis of the bone, four main difficulties are encountered.

In the types of motor drills more commonly used (excluding the cable-drive type), the motor will not lie flat enough against the extremity, so that the hole can be properly directed. The long drill point overcomes this by allowing the motor to be placed so far from the incision that it can be held close to the patient, thus making almost any angle possible.

When the drill point rests on the soft tissues at the end of the wound from which the hole is being drilled, the tissues are badly traumatized. The sleeve completely shields the soft tissues from the drill point, because the latter runs inside the sleeve and the sleeve does not turn.

In drilling holes at an acute angle, the tip of the drill point frequently skids about, when the hole is being started. This can be overcome very easily with the extension drill with sleeve, by grasping the sleeve firmly and holding the drill point in the desired place.

The fourth difficulty is that the drill point is sometimes too short to go through the bone. This is overcome by the long extension on the drill point.

It has been found that the extension drill with sleeve is of great value in drilling holes in bone at odd angles, particularly the hole required in the Nicola operation. It facilitates the drilling, saves operating time, reduces trauma to the soft tissues, aids in the accurate placing of the hole, and obviates the danger of the drapes catching on the drill point and becoming wound around it.

News Notes

THE AMERICAN ACADEMY OF ORTHOPAEDIC SURGEONS

By unanimous vote of its Executive Committee, The American Academy of Orthopaedic Surgeons has postponed to an indefinite date the Thirteenth Annual Convention, which was scheduled to be held in Chicago, January 21 to 24, 1945. This action was taken in compliance with the request of the Office of Defense Transportation.

The Fellows of the Academy elected during the past year are the following:

Dr. Alexander Philip Aitken, Boston, Massachusetts.
Dr. Harry B. Allison, Tacoma, Washington.
Dr. Alvin M. Arkin, New York, N. Y.
*Dr. Sam W. Banks, Chicago, Illinois.
Dr. William P. Bartels, Garden City, New York.
Dr. Clarence W. Betzner, Cincinnati, Ohio.
Dr. Donald W. Blanche, South Pasadena, California.
Dr. Henry Briggs, East Orange, New Jersey.
Dr. Brandon Carrell, Dallas, Texas.
*Dr. Francis J. Cox, New Orleans, Louisiana.
*Dr. Anthony F. De Palma, Newark, New Jersey.
Dr. Douglas D. Dickson, Oakland, California.
*Dr. Kerwin Armand Fischer, Louisville, Kentucky.
*Dr. John D. B. Galloway, Minneapolis, Minnesota.
*Dr. J. Neill Garber, Camp Bowie, Texas.
Dr. Harold W. Gehring, Detroit, Michigan.
*Dr. Everett Moore George, Des Moines, Iowa.
*Dr. David Goldberg, New York, N. Y.
*Dr. James William Graham, Sioux City, Iowa.
*Dr. Walter C. Graham, Santa Barbara, California.
*Dr. Ronald S. Haines, Phoenix, Arizona.
Dr. Bernard Mark Halbstein, Long Branch, New Jersey.
Dr. Delbert Hand, San Francisco, California.
*Dr. Charles U. Hauser, Cincinnati, Ohio.
Dr. George Washington Holmes, Winston-Salem, North Carolina.
*Dr. J. Howard Johnson, Milwaukee, Wisconsin.
*Dr. Robert W. King, Pasadena, California.
*Dr. Earl S. Leimbacher, Joliet, Illinois.
*Dr. Irwin Snyder Leinbach, Reading, Pennsylvania.
*Dr. Allen S. Lloyd, Washington, D. C.
Dr. Ian MacKenzie, Tulsa, Oklahoma.
Dr. Ira O. McLemore, Seattle, Washington.
Dr. Arthur A. Michele, New York, N. Y.
*Dr. Abraham Myers, Philadelphia, Pennsylvania.
Dr. Lawrence Noall, Portland, Oregon.
Dr. Maurice F. O'Connell, Hartford, Connecticut.
*Dr. Darrell O. Overpeck, Fresno, California.
*Dr. Edward Parnall, Denver, Colorado.
Dr. Fred A. Polesky, Los Angeles, California.
Dr. M. John Rowe, Jr., Long Beach, California.
*Dr. F. I. Schwartzberg, Paterson, New Jersey.
Dr. James W. Shumate, San Francisco, California.
Dr. Harvey W. Sigmond, Indianapolis, Indiana.
Dr. Homer H. Stryker, Kalamazoo, Michigan.
Dr. F. Eberle Thornton, Iowa City, Iowa.
*Dr. W. P. Warner, Atlanta, Georgia.
Dr. George Whiston, Casper, Wyoming.
*Dr. Irving Wolin, Chicago, Illinois.
Dr. Charles Francis Wood, Louisville, Kentucky.
Dr. H. Herman Young, Rochester, Minnesota.

* Now in Military Service.

The Executive Board of the **American Public Health Association** announces that the Third Wartime Conference and 74th Annual Meeting, and meetings of related organizations, will be held in Chicago, Illinois, the week of September 17, 1945, with headquarters in the Hotel Stevens.

The American College of Surgeons, in expanding its program of Graduate Training in Surgery to assure adequate opportunities for advanced training in surgery, particularly for recent medical graduates when they return from Service with the Armed Forces, has enlarged its headquarters staff in Chicago and announces the following appointments effective immediately:

Major General Charles R. Reynolds (M.C., retired), former Surgeon General of the United States Army, has been appointed Consultant in Graduate Training in Surgery.

Dr. George H. Miller, formerly Dean of the Faculty of Medicine and Chairman and Professor of the Department, American University of Beirut, Lebanon, Syria, has been appointed Director of Educational Activities.

The Department of Graduate Training in Surgery is under the general direction of Dr. Malcolm T. MacEachern, Chairman of the Administrative Board, working with that Board, and responsible to the Committee on Graduate Training in Surgery, of which Dr. Dallas B. Phemister of Chicago is Chairman, and to the Board of Regents.

Surveys of hospitals for Graduate Training in Surgery have been conducted since 1937 by the College. When the war ends in Europe, in order to satisfy the demands of men whose training in surgery was interrupted by war service, together with those of current medical graduates, sufficient opportunities should be ready to offer approved training to men who wish to become surgeons, Dr. MacEachern declares, adding that a competent surgeon according to present-day ideas requires a preparation of three or more years of systematic, supervised graduate training in general surgery or a surgical specialty, following a general internship and graduation from an acceptable medical school.

The biographical data of the first two editions of the **Directory of Medical Specialists** included only positions (internships, residencies, or assistantships) held during the course of training of men up to the time of their certification by the American Boards, and hospital and medical school staff positions then currently held.

In the Third Edition, it is desired to extend this data to include all formal hospital and medical school appointments, with dates held, even though now resigned, as well as records of all military service, including commissions and dates, either in World War I, in the Reserve forces in peace time or in the present War.

Thus, a chronologically complete sketch of a Diplomate's entire career is to be included in this Third Edition of the Directory.

Membership or fellowship in national or sectional (not local) special societies, and national general societies, with offices held, and dates, in any of these, should be reported.

Membership in recognized international medical societies may be included, but honorary or other membership in foreign medical societies should not be reported.

Reference to the Second Edition (1942) of the Directory may be made for lists of medical societies to be included in one's biographical sketch.

Families or secretaries of men absent in military service are asked to complete or correct previous listings on new forms now being mailed to those eligible for inclusion in the Directory. Only those certified by an official American Board can be included.

The foregoing notice is published in response to many inquiries, to assist those certified by the American Board who are now engaged in correcting their previous listings, or preparing new sketches for the Third Edition of the Directory to be published early in 1945.

Communications should be addressed to the Directory of Medical Specialists, 919 North Michigan Avenue, Chicago 11, Illinois.

BARUCH COMMITTEE ON PHYSICAL MEDICINE

The Administrative Board of the Baruch Committee on Physical Medicine has announced the granting of an additional total sum of $185,000.00, which is being given by Mr. Bernard M. Baruch for the further advancement of the program in physical medicine and the physical rehabilitation of those disabled in the War. This sum has been divided into seven grants as follows: $50,000.00 to the Massachusetts Institute of Technology, Cambridge, Massachusetts; $40,000.00 to the Medical School of the University of Minnesota, Minneapolis, Minnesota; $30,000.00 to the Medical School of Harvard University, Boston, Massachusetts; $30,000.00 to the Medical School of the University of Southern California, Los Angeles; $15,000.00 to the Medical School of the University of Iowa, Iowa City; $15,000.00 to the Medical School of the University of Illinois, Chicago; and $5,000.00 to Marquette University Medical School, Milwaukee, Wisconsin.

The grants to the Massachusetts Institute of Technology and to the University of Minnesota are in addition to the gift of $1,100,000.00 made by Mr. Baruch in April of 1944, at which time grants were made to

Columbia University College of Physicians and Surgeons, New York University College of Medicine, the Medical College of Virginia, and for minor research and fellowship programs for the advancement of physical medicine.

The present gift to the Massachusetts Institute of Technology is in support of a five-year program of training and research in electronics, instrumentation, and physics in relation to medicine, to be carried on under the auspices of the Department of Biology and Biological Engineering. It was the conviction of the Scientific Advisory Committee of the Baruch Committee on Physical Medicine that Baruch Fellows and other physicians should have more than a superficial knowledge of the physics and technology underlying the physical methods and instrumentation used in this field, and it was suggested that training in this aspect might effectively be centered at the Massachusetts Institute of Technology. The program will be under the general supervision of Dr. Francis O. Schmitt, Head of the Department of Biology and Biological Engineering, and under the immediate supervision of Dr. K. S. Lion, Assistant Professor of Applied Biophysics, who is an expert in physical instrumentation. Mr. Baruch has been particularly interested in the important field of electronics as applied to medicine.

The grant of $40,000.00 to the University of Minnesota is to support the development of a three-year teaching and fellowship program in physical medicine. The primary objective of the program is the furtherance of fundamental training of research workers and teachers in the field of physical medicine.

The other grants have been allocated from the fund of $200,000.00 given by Mr. Baruch in April. The sum of $30,000.00 was granted to Harvard University Medical School for the establishment of a three-year program to provide fellowships or residencies to be used for the benefit of qualified physicians who are selected to be trained in this field. This sum will be administered by a standing Committee on Physical Medicine recently appointed by Dean C. Sidney Burwell of the Harvard Medical School, composed of Dr. J. B. Ayer, Dr. D. Denny-Brown, Dr. W. T. Green, Dr. J. H. Means, Dr. A. L. Watkins, and Dr. E. M. Landis (Chairman). Appointments to the fellowships, which generally carry stipends of $2,500.00, will be made annually, but may be renewed to provide up to three years of specialized study and research. Emphasis will be placed upon training a few men in basic research and clinical investigation.

Unusual opportunities for clinical experience and research in the psychological and psychiatric aspects of physical medicine will be available at Harvard. The first year will be wholly or in part devoted to basic research, related to physical medicine in one of the preclinical sciences, such as physiology, anatomy, or biophysics. The second year will be spent in clinical training in physical medicine at the Massachusetts General Hospital and other hospitals affiliated with the Harvard Medical School. In the third year, fellows will be assistants in physical medicine with clinical responsibilities. For candidates with extensive previous training, one-year clinical fellowships will also be granted. Applicants must have an M.D. degree from an approved medical school, and a minimum of one year of internship in an approved hospital. Applications may be obtained from the Dean, Harvard Medical School, 25 Shattuck Street, Boston 15, Massachusetts.

The sum of $30,000.00 is granted to the University of Southern California to inaugurate a program of teaching and research in physical medicine in its Medical School. The sum of $15,000.00 is granted to the University of Illinois to inaugurate a teaching program in physical medicine at its Medical School. The sum of $15,000.00 is granted to the Medical School of the University of Iowa to assist in a joint research and teaching program concerning the effectiveness of different methods of applying heat to the deep tissues of the human body. Finally, the sum of $5,000.00 is granted to the Medical School of Marquette University, Milwaukee, Wisconsin, for continuance of research in the physiology and pathology of nerves and muscles, as related to physical medicine.

The Baruch Committee will now turn its main attention toward the adequate development of the centers already established, toward providing advice in the organization of proper teaching of physical medicine in medical schools and, through its Committee on War and Postwar Physical Rehabilitation and Reconditioning, will attempt to promote proper development of physical medicine in the rehabilitation and reconditioning of both military and civilian casualties of war. The Board feels that Mr. Baruch's gifts have served as a means of providing prompt coordination of the entire program for rehabilitation of our wounded and for the provision of the trained personnel so greatly needed in activating this program.

MICHAEL HOKE

1874–1944

"The field of action is not the field of intellect: it is the field of character. It is not the intensity but the duration of ideals that makes a great man."

This wise observation of Elihu Root is peculiarly applicable to the life of Dr. Michael Hoke, internationally known orthopaedic surgeon, great teacher, kindly counsellor, and friend.

Dr. Hoke was born in Lincolnton, North Carolina, on June 28, 1874. He was the son of the well-known General Robert F. Hoke and Lydia Van Wyck. General Hoke was, we believe, the youngest Major General in the Confederate Army.

Dr. Hoke's early years were spent in Raleigh, North Carolina. Entering the University of North Carolina, he received the degree of Bachelor of Science in Electrical Engineering in 1893 and was captain of the famous football team of that year. In 1895 he received the degree of Doctor of Medicine from the University of Virginia. Postgraduate study and research then followed at the Medical Schools of Johns Hop-

kins and Harvard. In 1897, he began private practice in Atlanta, Georgia, specializing later in orthopaedic surgery.

On April 20, 1904, he was married to Miss Laurie H. Harrison of Atlanta. The union was a completely happy one, Mrs. Hoke entering fully into both his professional life and his many outside interests. Mrs. Hoke and their two children, Mrs. Charles McGhee of Beaufort, South Carolina, and Mrs. Edward Jastrum of St. Louis, Missouri, and two grandchildren survive him, as does his brother, Mr. Van Wyck Hoke of Yanceville, North Carolina.

Dr. Hoke was a member of The American Orthopaedic Association and its President from 1925 to 1926, presiding at the Annual Meeting of the Association held in Atlanta in 1926. He was a Fellow of The American Academy of Orthopaedic Surgeons. He was one of the five Orthopaedic Consultants for the Shriners' nation-wide chain of Hospitals for Crippled Children, which movement he had sponsored; he was also an important member of the Advisory Board of the Alfred I. Du Pont Institute for Crippled Children at Wilmington, Delaware.

The University of North Carolina conferred on him the honorary degree of Doctor of Laws in 1931. In this same year, at the insistence of President Roosevelt, he accepted the appointment of Medical Director of the Institution for the Treatment of Infantile Paralysis at Warm Springs, Georgia, resigning this position in 1935 to resume his private practice in Atlanta.

Dr. Hoke's contributions to orthopaedic surgery have been many and have been internationally recognized. The original and valuable operative methods he devised for the treatment of certain disabilities of the feet are still known as "Hoke's operation for claw foot" and "Hoke's arthrodesis".

Hoke was a great teacher as well as a great surgeon. He inspired countless young men to acquire surgical skill and to emulate the highest standards of professional conduct which he exemplified. He ploughed the field of medicine deeply, leaving the soil more productive for the labor of those younger physicians who had received their inspiration from him. "History shows you men whose master touch not so much modifies as makes anew"—Browning, had he known him, might well have placed Hoke in this category.

Dr. Hoke's chief relaxations were golf and hunting with the dogs, and he held membership in the Piedmont Driving Club and in the Druid Hills Golf Club. He was a thorough sportsman in the best sense of the word, loving "the wide-open spaces" and "the great out-of-doors".

Although Michael Hoke always felt intensely, and was unswerving in his loyalty to the South, he maintained an unusual breadth of view and was remarkably free from prejudice. On one occasion, he took a northern friend to see the great southern War Memorial on Stone Mountain which was then only partly finished, but the architect's drawings of the completed project were on view and were very impressive. Behind the key figure of General Robert E. Lee, the sculptor had planned to carve a group of other Confederate generals, one of whom would undoubtedly have been Doctor Hoke's famous father, Major General Robert F. Hoke. Dr. Hoke greatly admired the conception and was deeply moved at the thought of what the superb memorial would mean to the South.

As he and his northern friend were moving away, Hoke said to him, "I wish Borglum (the sculptor) would do one more thing. I wish he would place the figure of Abraham Lincoln on the summit of the mountain looking down on the whole group." To Hoke "the war was over", and he had recognized the spirit of the Great Emancipator and wished the South as well as the North to pay him tribute.

This slender ascetic looking man with dark and piercing eyes, a friendly smile, and a delightfully keen sense of humor must have been a sturdy youth in his student days. In later life, pulmonary disease and his strenuous work slowly sapped his strength but never his *bonhomie* nor his endearing kindness.

In 1937, he retired from private practice and moved with his family to the lovely old town of Beaufort, South Carolina. They called their home "Windy Marsh" and for a while Dr. Hoke's health was better, and his passing has come as a shock to his numberless friends.

American Medicine has lost a great orthopaedic surgeon and a great teacher. His standards of both practice and conduct will always inspire physicians, young and old, who have been fortunate enough to catch his spirit.

Justice Oliver Wendell Holmes has given us his ideal of living. "Life is painting a picture, not doing a sum; to hammer out as compact and solid a piece of work as you can; to try to make it first rate and to leave it unadvertised."

Michael Hoke completely exemplified this ideal.

Current Literature

Lectures on Reconstruction Surgery. Selected from the Instructional Courses of the Twelfth Annual Assembly of The American Academy of Orthopaedic Surgeons. Edited by James E. M. Thomson, M.D. Ann Arbor, Michigan, Edwards Brothers, Inc., 1944. $8.00.

To present a critical analysis of this admirable compilation of the work of a representative group of specialists in the field of reconstructive surgery cannot be done in the space that may be allotted for a review.

All this reviewer can do is to liken it to a symphony, where each instrument having a part is played by an expert in his line. Some instruments have a more important rôle perhaps than others, but no one is any less well played than another, and the summation of effort is a harmonious rendition.

To select some particular papers for special commendation would be invidious; they are all exceedingly well illustrated, clearly presented and are invaluable at this time for anyone who wishes to have the most recent information on the subjects discussed.

Surgery of the Hand. Sterling Bunnell, M.D. Philadelphia, J. B. Lippincott Company, 1944. $12.00.

It is seldom that a book on surgery deserves to be called great. This adjective, often used so carelessly, can be applied with all its implications to "Surgery of the Hand" by Sterling Bunnell. Peculiarly enough, another great surgical treatise, Kanavel's monograph, also dealt with the hand, but limited itself to infections.

Bunnell's book is all-inclusive; nothing connected with the hand has been omitted. The author, in an age of intense specialization, has risen above the confines of a single surgical specialty, and has combined the art of the plastic, orthopaedic, and neurological surgeons. This had to be, for, as he states in his preface, "Trauma involves all types of tissue, irrespective of the artificial divisions of our specialties. . . . As the problem is composite, the surgeon must also be."

As one reads the succeeding pages, one realizes both from the text and the illustrations that here is a surgeon who has learned to "face the situation and equip himself to handle any and all of the tissues in a limb". More than that, his book illustrates his intense desire to teach, to make his own rich experience available to all who want to learn. He has spared nothing to make himself clear, no detail in technique has been too minute to defy careful description, provided it brought out an important principle. His style is that of precise exposition which at times, by its very simplicity, acquires beauty. Take for instance the opening paragraph of the chapter dealing with "The Normal Hand":

> "Next to the brain, the hand is the greatest asset to man, and to it is due the development of man's handiwork. It is also an organ of expression and a special sense organ for stereognosis. Our brains are crowded with memories and conceptions of objects and actions which have been built up and developed by sensation and use of our hands. Through hands we have acquired by feeling much of our knowledge of shapes and textures of the objects of this world. Our very thoughts are linked with the sensations and actions of our hands, not only in our fundamental activities concerning shelter, food, combat, and perpetuation, but in constructing, such as building, drawing, sculpturing, and even thinking."

The book is divided into four parts. The first deals with phylogeny and comparative anatomy, and the description of the normal hand; the second with reconstruction of the hand; the third with injuries and infections; and the fourth with miscellaneous conditions,—such as congenital deformities, vasomotor changes, and tumors. Of these, the most important is the second, "Reconstruction of the Hand". The author deals in succession with skin and flexion contractures, bone deformities, stiff joints, injuries to nerves, tendons, and the intrinsic muscles, and, in a final section, to the arm in its relation to the hand.

Though many of the ideas have already appeared in Bunnell's previous publications, it is only when the subject is presented as a whole that one realizes the originality and the unity of Bunnell's contribution to surgery. As an example, he was the first to suture the digital nerves, but this delicate surgical feat was done not as an end in itself, but to aid in the reconstruction of a finger the tendons of which had also been severed. Surgery of the skin, of the bones, of tendons and nerves are all correlated to yield the maximum restoration of function.

It is hard to speak with restraint about this unique volume. It represents to your reviewer the ideal scientific publication; it is brilliantly original, concise yet thorough, so sincere that the honesty and high intent of the author speak in every line. It marks an important milestone in surgical advance. It will assuredly come to be regarded as a classic for those who, like Bunnell, aim to restore power to the hands of the maimed.

Artritis Tuberculosa de la Cadera. Dr. V. Sanchís Olmos. Madrid, Edicones *Cirugía del Aparato Locomotor*, 1944.

In this monograph on tuberculosis of the hip joint, the best to appear to date in any language, the author has blended skillfully our knowledge of tuberculous infection in general and his wide experience in the treat-

ment of this special type of infection at the *Hospital Central de la Cruz Roja*. The book is well illustrated, and there is a large bibliography. Much of the recent European thought, which has been excluded from American readers, is critically summarized. The author is writing for a Spanish audience, for the purpose of disseminating knowledge of the treatment of tuberculosis of the bones and joints. There has been a great increase in morbidity from tuberculosis in Spain following the recent War.

The symptoms observed in tuberculosis of the hip are dependent upon the oscillations of allergy, and, in this respect, are similar to those seen in pulmonary infection. Osseous or articular involvement occurs during the secondary period of allergy, by the hematogenous route from some primary visceral implantation, and results either in medullitis or synovitis. He feels that the doctrines of Ranke and Redeker, while helpful, do not explain fully the pathological phenomena. He agrees with Auer that infection is enhanced in tissues whose reactivity has been altered, for example, by trauma. Repeated microtrauma may favor the localization. There may be primary involvement of the synovial membrane, infection of the synovial membrane secondary to an abscess, or primary involvement of bone. Usually the disease is so far advanced when seen that the primary focus cannot be determined. The pathological reaction in the bone or joint may be caseous, exudative, or granulomatous during the secondary stage of the tuberculosis. Urbach attempts to explain the vigorousness of the reaction and the necrosis of tissue which occurs upon the basis of the relative proportion of antigen and antibody present in the tissues. Caseation is rare in synovitis, but is common in osseous lesions. Vascularization of the tissues about the hip joint explains the predilection for certain areas. Infection is rarest in the ischium and pubis. Primary synovitis is rare indeed. Osteo-arthritis originating in an osseous focus often leads to extensive necrosis and abscess. Osteo-arthritis originating in a synovial focus is often limited to cartilaginous destruction and early fusion of the joint.

There is a wide immunobiological lability with great variation in symptoms and reparative response. If the state of hypersensitivity is much prolonged, abscess, fistula, and death may occur. The tertiary phase of tuberculous infection often leads to unsound healing. The only type which leads to sound, anatomical cure is the rapidly exudative type which produces conditions favorable for osseous fusion. The appearance of abscess is in direct proportion to the violence of the exudative phenomena.

Deformities are divided into two types which may appear in both the secondary and tertiary phases of the infection: (1) contractures or ankylosis in a bad position and (2) loss of all normal anatomical relationships with pathological dislocation. Trophic disturbances and interference with growth are not uncommon. Perifocal hyperaemia provokes local acidosis, which frees calcium salts. This is a constant phenomenon in tuberculous infection, and is most marked in the exudative type. The osteoporosis which results lessens the mechanical resistance of the bone. Bone atrophy is also partly the result of immobilization. Decalcification diminishes with regression of exudative phenomena. Epiphysiolysis is rare. Ossification may be increased under the periosteum. Variations in growth may be seen in different parts of the epiphysis.

Early diagnosis by roentgenographic examination is difficult. The first sign is focal osteoporosis. Serial roentgenograms will show the progression of the lesion. (Lesions in the cartilage appear late.) The common physical signs of tuberculous infection are usually found. A negative reaction to tuberculin almost completely eliminates the diagnosis of tuberculous infection. The sedimentation rate of the erythrocytes is moderately elevated. Biopsy is occasionally necessary. The differential diagnosis is outlined. The prognosis is always serious.

Treatment should be both general and local. Under the general treatment, the author mentions sunlight, adequate nutrition and calcium, and sulphonamides for sinuses. Locally, osseous ankylosis with the hip in a good position is sought. Fibrous ankylosis can be regarded as an inactive tuberculous focus cured clinically, but not anatomically. Local extirpation removes only one latent focus and can only be resorted to in areas easily accessible anatomically. The position of ankylosis will be dependent upon the socio-economic status of the patient. The joint is rarely preserved in the healing of tuberculosis. Even Rollier and Kisch now speak of arthrodesis as the treatment of choice. During the secondary phase of infection, general treatment is fundamental, and orthopaedic treatment which facilitates this should be given.

Surgical intervention should be undertaken during the tertiary period. Age is no contra-indication to surgery. The author does not hold to the teaching of Sorrell and the Congress of 1927, which advocated conservatism in childhood, arthrodesis in maturity, and amputation in the aged. The author gives the following as his formula of therapy: in the tertiary phase, surgical treatment directed to ankylosis; in the hyperergic phase, conservative treatment; in the phase of local hyperergia, extra-articular intervention when the general state of the patient indicates.

In minor tuberculous affections and where there is a para-articular focus, simple prolonged rest in bed may be all that is required. Synovitis, osteo-arthritis, and juxta-articular foci require absolute immobilization. If there is a fistula, a bilateral spica with a window is needed. The hip is maintained in 10 degrees of flexion, 15 degrees of abduction, and no rotation. The author prefers continuous traction to a plaster cast, because in traction the skin is exposed more fully to the sun and air.

Fusion is carried out by a procedure similar to the Hibbs-Chandler technique. Contractures are corrected by traction,—skeletal traction if necessary. Vicious ankylosis is corrected by subtrochanteric osteotomy. Flexion depends upon the vocation of the individual. Abduction should be 5 degrees in men and 15 degrees

in women. Recent dislocation is reduced by traction. After reduction of a dislocation, an athrodesis is performed. Shortness of the extremity can be improved up to six centimeters by leg lengthening. If the difference is greater than this, the sound leg can be shortened. In involvement of both hips, an arthroplasty can be attempted on one side, after the arthrodesis has healed. Motion should be preserved in one hip if possible, during the healing of the tuberculosis.

The author feels that patients with such infection should not be treated on the general service of hospitals, but should be segregated in special hospitals or sanitoria where specialized care can be given.

TREATMENT BY MANIPULATION IN GENERAL AND CONSULTING PRACTICE. A. G. Timbrell Fisher, M.C., M.B., Ch.B., F.R.C.S. (Eng.). Ed. 4. New York, Harper & Brothers, 1944. $4.75.

The new edition of this work on manipulative surgery is written because of the author's belief in the importance of manipulative treatment of orthopaedic conditions resulting from war injuries. After a short historical introduction, the lesions benefited by this type of therapy are discussed according to the pathological findings.

There are four main classifications used: (1) articular or periarticular adhesions, (2) functional or hysterical conditions of joints, (3) subluxations and dislocations of joints, tendons, or intra-articular discs, (4) adhesions in connection with muscles, tendons, or fascia. In the prevention of adhesions, early motion is stressed and the dangers of prolonged rest and splintage are emphasized. Instruction in the degree and type of motion permitted in a variety of pathological conditions is carefully presented. As the primary indication for manipulation is the presence of adhesions, a chapter is devoted to their diagnosis.

The actual procedure of manipulation, preferably under an anaesthetic such as pentothal, is described for all the major joints, with suitable illustrations and brief case histories of the clinical findings. Contra-indications to manipulation, such as tuberculosis and neoplastic disease, are pointed out. Although one feels that the author expects almost universally good results, the use of other measures—such as splintage, traction, and surgery—are recommended in some instances. The importance of adequate physical therapy in the after-care of manipulative cases is repeatedly stressed. A chapter is devoted to description of the technique in use of heat, massage, and exercises. The author further states that no medical man should perform a manipulation unless he has made a study of massage, muscle re-education, and the methods of physical treatment that are of use in after-care.

Although among American physicians "manipulation" frequently has had bad connotations, the subject is presented in this book in a fairly cautious and studied manner. One might wish to have more precise information on the problem of choice of case to manipulate rather than broad statements, such as "The most frequent indications for (spinal) manipulations are those cases in which adhesions or scar tissue in muscles, ligaments, or fasciae have followed either toxic or infectious conditions, or ligamentous or muscular injuries". There is, however, much valuable information worthy of study by orthopaedic surgeons and those specializing in physical medicine.

STRUCTURE AND FUNCTION AS SEEN IN THE FOOT. Frederic Wood Jones, D. Sc., F.R.S., F.R.C.S. Baltimore, The Williams & Wilkins Company, 1944. $7.50.

Professor Wood Jones's eminent position as an anatomist and physical anthropologist and the importance of the foot to man's locomotor mechanism should amply recommend this book to all orthopaedic surgeons. The text is interestingly written and thought-provoking. Even though the author may not win ready acceptance of all his statements, he will not fail to stimulate a healthy, thoughtful reaction among his readers.

The opening chapter affirms the unique and highly specialized character of the human foot. The distinctive design of the foot separates mankind from all other forms of vertebrate life, and as an organ, its structures have been molded specifically for one purpose,—"support and propulsion of the body in bipedal orthograde progression". He emphasizes, also, the basic difference between hand function and foot function, and warns that the structural homologies in these two organs should not be allowed to obscure a clear recognition of the difference in our approach to the clinical considerations of foot disabilities. The human hand is primitive in its design, and is little changed from the hands of all lower primates; its superior qualities are represented only in a higher degree and range of skilled actions. In contrast, the human foot has been so extensively remodeled for direct interaction with the force of gravity (beneath the weight of our bodies), that its former handlike, grasping characteristics have become almost completely replaced by the specialized structural changes required for stable support and propulsive leverage.

The author's discussion of muscle action should also be of more than ordinary interest to orthopaedic readers. Not only does the author recognize the "controlling" action of the extrinsic muscles of the foot, in contrast to the "supporting" action usually ascribed to them, but he also explains the *reversed* direction of their action, as compared with the muscles of the hand. In the forearm, the muscle *origins,* located proximally, serve as the fixed point from which movements of the digits and hand are effected; in the lower extremity, the tendinous *insertions* upon the distal bony segments serve as the fixed points from which muscle

action is enabled to control posture and the movements of body weight. Both of these observations have practical therapeutic bearing on corrective and surgical work on the foot.

The book is a comprehensive treatise of all the tissues entering into the make-up of the foot,—skin, fascia, muscles, ligaments, bones, joints, and vascular and nerve structures. As might be expected, the discussion of these tissues is accompanied by interesting comments relating to their development, both phylogenetic and ontogenetic. The author has avoided any attempt to supply a definite evolutionary background. His chapter on phylogeny consists chiefly of a critical statement on the views held by different writers regarding the point of human origin. The concept usually associated with his name places that point far back in a "tarsioid" branch of early primate life. His claims to the general acceptance of that belief are somewhat surprising, and seem as controversial as the "tarsioid" theory, itself, which he so strongly advocates. Naturally, his interpretations of development are influenced by that concept.

The text reflects Professor Wood Jones's wide familiarity with the literature contributed by older and more recent writers on the various phases of the subject. He brings in references that enhance interest and will inevitably broaden the reader's viewpoint. However, the book is distinctly the product of a *morphologist.* This is strikingly indicated by the author's discussion of the "metatarsal formula". Here he discounts, almost derides, the possibility of there being any functional or clinical significance in a short first metatarsal bone; he prefers to regard that condition as "the accepted normal of all anatomists". Such apparent unwillingness to permit a morphological conclusion to be disturbed by the physiological studies and clinical observations of other writers hardly contributes to the strength of Professor Wood Jones's arguments, but does not detract from the colorfulness of the presentation. In fact, it is in the physiological phase that the book invites a feeling of disappointment, because, after having identified the foot as an organ designed specifically for its interaction with the force of gravity (as imposed by body weight), the author fails to follow up his statement with further consideration of that essential aspect of foot function. It is like reading a treatise on the eye in which every structure related to the eyeball is fully discussed, but no mention is made of refraction, the phenomenon whereby the vital purpose of the eye as the organ of vision becomes fulfilled. In the same way that an orderly transmission of light rays through the eyeball is a basic factor in eye function, the behavior of weight stresses (gravity) within the foot structure comprises the fundamental phase of foot function. However, the intimate morphology of the eye was a prerequisite to the understanding of the refractive elements of sight. The work of Professor Wood Jones is to be regarded as an important contribution to our morphological knowledge, which will prepare the way toward clearer understanding of the less obvious, but more basic phase of the foot's function.

ORTHOPAEDIC SURGERY. By Walter Mercer, M.B., Ch.B., F.R.C.S. (Edin.), F.R.S. (Edin.). With a Foreword by Sir John Fraser, Bart., K.C.V.O. Ed. 3. London, Edward Arnold & Co., 1943. 45 shillings. Baltimore, The Williams & Wilkins Co., 1943. $12.00.

The third edition of Mercer's textbook on orthopaedic surgery has been revised chapter by chapter to include new material on each subject. The sections on Circulatory Disturbances, Affections of the Back, Knee, Shoulder, and Foot, and Infections of the Hand, have been largely rewritten.

The text is well illustrated with photographs, line drawings, and roentgenograms which add much to the clear presentation of the anomalies and the diseases of bones and joints.

The author has indicated his choice of treatment and operative procedure in some conditions.

The text is thoroughly indexed, and the complete bibliography, including many American and British authors, should prove an invaluable reference to the student or doctor.

REHABILITATION, RE-EDUCATION AND REMEDIAL EXERCISES. Olive F. Guthrie Smith, M.B.E., C.S.M.M.G., T.M.G. With a Foreword by Lord Horder, G.C.V.O., M.D., F.R.C.P. Baltimore, The Williams & Wilkins Company, 1943. $6.00.

The physical treatment, described in this book by contributors distinguished in various fields of therapy, is confined largely to suspension exercises and pulley therapy. A revision of theoretical joint axes from an anatomical and physiological viewpoint, including plates which demonstrate planes and axes, precedes the classification of the various joints of the body.

The principles of re-education in flaccid and spastic paralyses are explained by means of a pendulum-suspension rhythm and muscle-timing apparatus.

Voluntary exercises are stressed, as are self-activated exercises, which employ simple appliances in the hands of a skilled therapist. Long helical or spirally curved springs are recommended for the treatment of enfeebled or injured muscles. They may be adjusted to the needs of the patient, so as to apply either assistance or resistance to the exercises.

Descriptions of the use of graduated faradic contractions for the stimulation of one group of motor nerves are included; group exercises, as used at the Berry Hill Hall Rehabilitation Center, are recorded; and different methods of muscle-testing are suggested.

Various pathological conditions and their treatment by relaxation and corrective exercises are considered, and illustrations show pulley and rope exercises for the lower and upper extremities.

As the title infers, the work is concerned chiefly with remedial and re-educational exercises. Apparatus and appliances play an important rôle in the book.

Other branches of physiotherapy are mentioned,—such as, heat, short wave and ultra-short wave, galvanic and sinusoidal currents, histamine ionization, and massage; however, these are considered as side issues rather than as part of a well-defined text.

The book is well and fully illustrated.

OPERATIONS OF GENERAL SURGERY. Thomas G. Orr, M.D. Philadelphia, W. B. Saunders Company, 1944. $10.00.

The expressed purpose of this excellent volume is the familiarizing of students with standard operations in all fields of surgery. Of special interest to the orthopaedic surgeon are: Chapter 4, "Amputations", Chapter 6, "Muscle, Fascia, and Bursa", and Chapter 7, "Tendons and Tendon Sheaths". Chapter 14, "Bones and Joints", has forty-six pages of concentrated orthopaedics, starting with the treatment of acute and chronic osteomyelitis, strongly advocating the method of Winnett Orr. In the treatment of fractures, standard operative procedures are described in regard to certain specific conditions, including fractures of the olecranon, head of the radius, condylar and supracondylar fractures of the humerus, patella, femoral condyles, and so on. The chapter concludes with descriptions of special operations,—such as those for the dislocation of the patella, dislocation of the shoulder, dislocation of the hip, acromioclavicular separation, injury to the semilunar cartilage of the knee, and hallux valgus. For each of these conditions, one or two standard procedures are described.

The chapters reviewed comprise only a small portion of the book, the rest of which includes descriptions of operations on the breast, thorax, circulatory system, digestive system, and many others. It is freely illustrated with distinctive drawings and diagrams showing step-by-step procedures in each of the standard operations. The book serves its purpose well in indicating to the student of general surgery not only the standard procedures in general surgery, but also in surgical specialties with which he should be familiar.

FRACTURES AND FRACTURE TREATMENT IN PRACTICE. Kurt Colsen, M.D. Ed. 2. Johannesburg, Witwatersrand University Press, 1944. 12 shillings, 6 pence.

This book of 150 pages is introduced to the students of the University of the Witwatersrand at Johannesburg by the Professor of Surgery, I. W. Brebner. It presents in Part I certain general considerations, intended to orient the student, who will find in Part II special fractures described and some form of treatment advised and pictured by line drawings. The author has made a brief review of the various fractures, depending very evidently upon the writings of Böhler and Watson-Jones.

The subject presented is one of the most important in surgery. Undoubtedly under the skilled presentation and instruction of the author, his students will receive adequate impressions of the close relationship between the problems attending fractures and those of many other specialties in surgery.

MICROBES THAT CRIPPLE. T. Arthur Turner. (Written and Illustrated under the Direction of Edward L. Compere, M.D.) Elyria, Ohio, The National Society for Crippled Children, Inc., 1944. $2.50.

This book is written for the layman. It presupposes no knowledge of science. From the construction of the microscope by Jansen in 1590 to the electron microscope of the present, with the field it opens, the story of the lens is traced. So too are the organisms revealed by the microscope. A little of the history of the recognition of their existence and of the men who first isolated and named them is given.

The classification of bacteria and other infectious agents is presented in an interesting, simple style. The principles of immunization are discussed, and the laboratory methods used are explained. The diseases produced by "crippling micro-organisms" are then described,—pyogenic osteomyelitis, tuberculosis, syphilis, and poliomyelitis. Rheumatic fever, arthritis, and gonorrhoea are recognized as "cripplers"; and the complications of various diseases of childhood are explained.

The last portion of the book is devoted to an exposition of the progress made in combatting these diseases,—the public health program with its educational aspect for the prevention of crippling, the history of chemotherapy, and the fight against poliomyelitis.

Such a book, written in cooperation with men whose lives are devoted to the correction and prevention of congenital and acquired deformities, has its place in medical literature. Written in language which the layman can understand, and presented in popular format with clever illustrations, it should have a wide reading. For the mother who has read this book, "microbes that cripple" will have fewer terrors.

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THE DEVELOPMENT OF SARCOMA IN BONE SUBJECTED TO ROENTGEN OR RADIUM IRRADIATION *

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From the Department of Surgery, University of Chicago

Roentgen or radium irradiation sufficient to cause epithelial changes has been followed not infrequently by the development of carcinoma. Although less common than carcinoma, sarcoma in a superficial ulceration of an irradiated field is a well-known complication. Occasionally sarcoma has developed in subjacent soft parts after exposure to x-rays or radium. Since bone is the most common primary site of sarcoma, it is reasonable to expect that, when subjected to irradiation, it too may undergo late malignant change. The purpose of this paper is to present three patients in whom irradiation appears to have been responsible for the development of bone sarcoma. In each of these cases the tumor arose in normal bone which had been in the field of irradiation directed toward an independent lesion.

EXPERIMENTAL SARCOMA OF BONE PRODUCED BY X-RAY OR RADIUM

Most experimental work on the production of tumors by irradiation has been concerned with carcinoma and with superficial sarcomata. Tumors have been produced inadvertently in bones close to areas of irradiated tissue. Marie, Clunet, and Raulot-Lapointe, in 1910, observed such a tumor while they were working on the relationship of x-ray burns and carcinoma. Theirs was the first report of experimental sarcoma of bone produced by irradiation. Lacassagne and Vinzent, in 1929, treated with 1000 roentgen units a bacterial abscess adjacent to the femur of a rabbit, and noted an osteogenic sarcoma six and a half months later. Lacassagne also produced a fibrosarcoma of the tibia thirty-six months after 1980 roentgen units had been delivered over an abscess near the bone. He deduced that chronic infection facilitates the production of sarcoma by irradiation.

In 1931, Schürch and Uehlinger implanted a 1-microgram radium needle subperiosteally in the jaw of a rabbit and left it in place for twenty days. One and a half years later a spindle-cell sarcoma, with areas of cartilaginous and osteoid tissue, was found. Sabin, Doan, and Forkner, in 1932, studied the effect of intravenous injections of 5.1

* Read at the Annual Meeting of The American Orthopaedic Association, Hot Springs, Virginia, June 2, 1944.

micrograms of radium chloride and also of 7.7 micrograms of mesothorium upon the bon marrow of rabbits. Osteogenic sarcoma was found subsequently in two of seven animal which survived eleven to nineteen months.

Schürch and Uehlinger, in 1935, placed vaseline impregnated with 2 to 5 microgram of radium or mesothorium in the femora of twenty-two rabbits. Eighteen to twenty-on months later five animals had sarcoma at the site of the implant. Three of the tumor were osteoblastic and two were polymorphous or spindle-cell sarcomata.

In 1936, Jentzer produced sarcoma in the skull of a rabbit by the application o radium. The same year Ross implanted platinum tubes containing 0.1 milligram radiun element in the thoracic wall of young rabbits; and an osteogenic tumor of a rib resultec in one animal.

Hellner, in 1937, in conjunction with his report of one clinical case of irradiatioı sarcoma, also described a polymorphous sarcoma, produced by repeated exposures of th lower end of the femur of a rabbit to radium. In the same year, Ludin directed to th tibia of a rabbit 8000 roentgen units over a period of six and a half months, and late found a chondrosarcoma.

In 1937, Daels and Biltris introduced a mixture of radium, paraffin, diatomaceou earth, and arsenious acid into the skulls of guinea pigs and two bone sarcomata resulted Schürch and Uehlinger's third paper reported sarcomata in 50 per cent. of animals whicl survived exposure to radio-active material for a long period. The same authors, in 1938 described osteogenic sarcoma in fourteen of twenty-one rabbits in which 0.005 milligram o mesothorium had been implanted twenty-one to twenty-nine months before. Daels and Biltris, in 1938, implanted collodion strips impregnated with radium sulfate into the pectoral muscles of fowls. Osteogenic tumors were found in two of the birds four to five years afterward.

Dunlap, Aub, Evans, and Harris, in 1944, reported osteogenic sarcomata which appeared in the vertebrae or pelvic bones in nine of thirteen rats fed 100 micrograms of

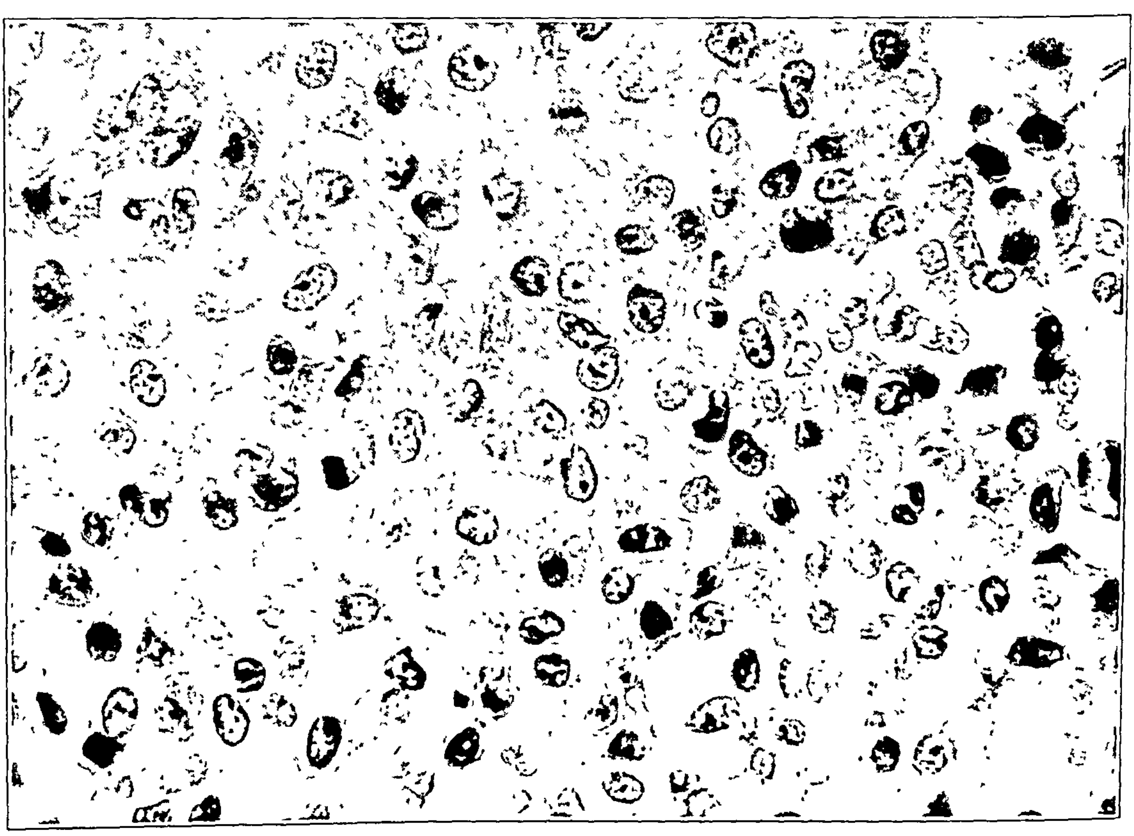


Fig. 1-A

Case 1. Photomicrograph (×300) of epiphyseal chondroblastoma of tibia.

FIG. 1-B

Roentgenograms four years after last roentgen exposure show irregular sclerosis at site of original epiphyseal tumor of tibia; partial destruction and replacement of the proximal end of fibula by mass of variable density.

radium. The average interval from the time of radium ingestion to discovery of the tumors was 365 days. Three of the tumors were successfully transplanted to other rats.

CLINICAL CASES OF OSTEOGENIC SARCOMA FOLLOWING IRRADIATION

There are reports in the literature of twenty-four patients who developed bone sarcoma following exposure to irradiation. Seventeen of these tumors resulted from roentgenotherapy for tuberculous arthritis. One followed similar treatment for acute arthritis. In six cases, bone sarcoma followed exposure to radium.

Beck, in 1922, reported three cases in which bone sarcoma had developed within three to five years after roentgenotherapy. In the same year Marsch recorded two similar cases which had followed repeated roentgen exposures for tuberculosis of the knee five and seven years earlier. In 1924 Beck added two cases. Baumann described in 1927 a patient who had had tuberculosis of the elbow and who, six years after repeated x-ray treatments, presented a sarcoma of the distal end of the humerus. In 1929 Jaruslawsky described a round-cell sarcoma at the knee which had appeared eleven years after roentgenotherapy for tuberculous arthritis. Hanke and Neuhaus, in 1930, added one case of chondrosarcoma of the humerus, noted four years after repeated x-ray treatments of a tuberculous elbow. Kuttner, in 1931, summarized the previously reported cases and added two. One of these was an osteosarcoma, found in the distal end of the femur which three years earlier had had repeated roentgen exposure during one year. His other case was a myeloid myeloma which appeared in the dorsal spine six and a half years after irradiation for tuberculosis of the same region.

Denks, in 1932, recorded a case of osteochondromyxosarcoma of the distal end o the femur, present six and a half years after excessive irradiation for tuberculosis of th knee. He also included Roedelius's case of sarcoma of the foot, noted ten years afte roentgenotherapy for tarsal tuberculosis. Oehlecker's case, included in this same report was of a spindle-cell sarcoma which was present six years after irradiation for an acut arthritis of the knee. Gruca, in 1934, reported a sarcoma containing cartilaginous an bony tissue. This tumor appeared five years after roentgen treatment of a tuberculou knee. Becker, in 1936, described a similar tumor which followed by ten years roentgeno therapy for tuberculous arthritis of a knee. Through accident an excessive amount wa administered. In 1937, Hellner noted a polymorphocellular sarcoma which develope in a metacarpal bone five years after roentgenotherapy for tuberculosis of the wrist.

The most spectacular example of bone sarcoma resulting from irradiation is foun in dial painters who repeatedly ingested minute amounts of radium, mesothorium, an radiothorium. Martland reviewed these cases and demonstrated radio-activity in al bones. Radiation necrosis was found chiefly in the jaw and in bones subject to weight an pressure. In five of eighteen fatal cases bone sarcomata were found. Martland state that in at least three living former dial painters sarcomata had been diagnosed.

Nørgaard, in 1939, observed in the proximal end of the tibia a fibrosarcoma whic he considered due to intra-articular injection, eight years before, of ten micrograms o radium chloride for chronic arthritis of the knee. In the same patient a shoulder join had been treated similarly. This joint showed evidence of radium necrosis of bone, bu no tumor. Both areas showed signs of radio-activity even after eight years, that of th amputated portion being equivalent to three to four micrograms of radium.

FIG. 1-C

Roentgenogram of chest ten months after thigh amputation shows metastatic tumor mass near the hilum of right lung.

REPORT OF CASES

CASE 1 H R, a man, twenty-three years old, entered the University of Chicago Clinics October 30, 1942, complaining of pain in the right ankle, and foot-drop of three and a half weeks' duration In 1936, when he was seventeen, he had had constant increasing pain in the right knee for which he had been admitted to a hospital A diagnosis of giant-cell tumor of the proximal epiphysis of the tibia was made, and local

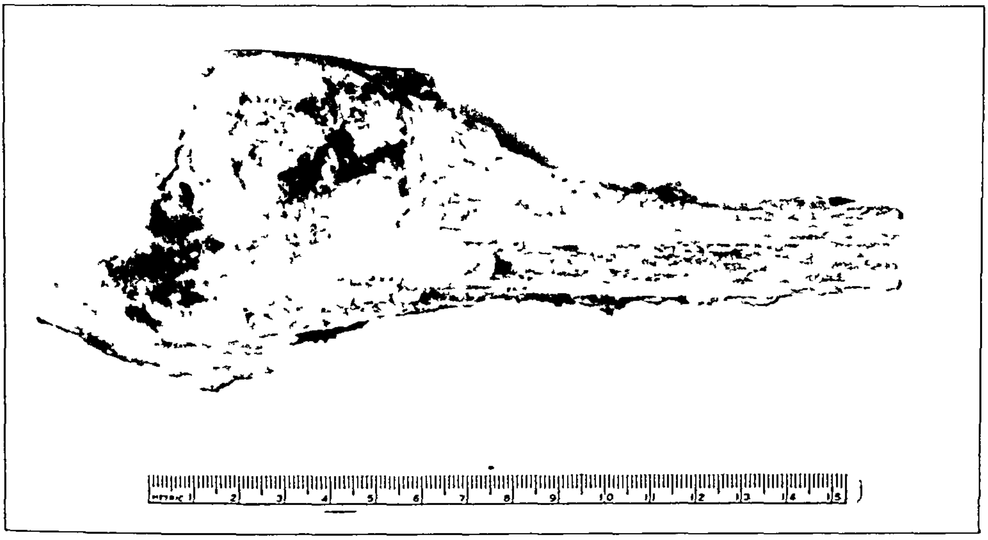


FIG 1-D
Photograph of frontal section through tumor of fibula

FIG 1-E
Roentgenogram of frontal slice through tumor and photograph of the section show destruction of the shaft of the fibula and irregular ossification in the tumor.

excision of the lesion was done. Microscopic examination of the tissue (Fig. 1-A) showed benign chondro-blastoma. From December 14, 1936, to May 20, 1937, he received over anterior, posterior, and latera

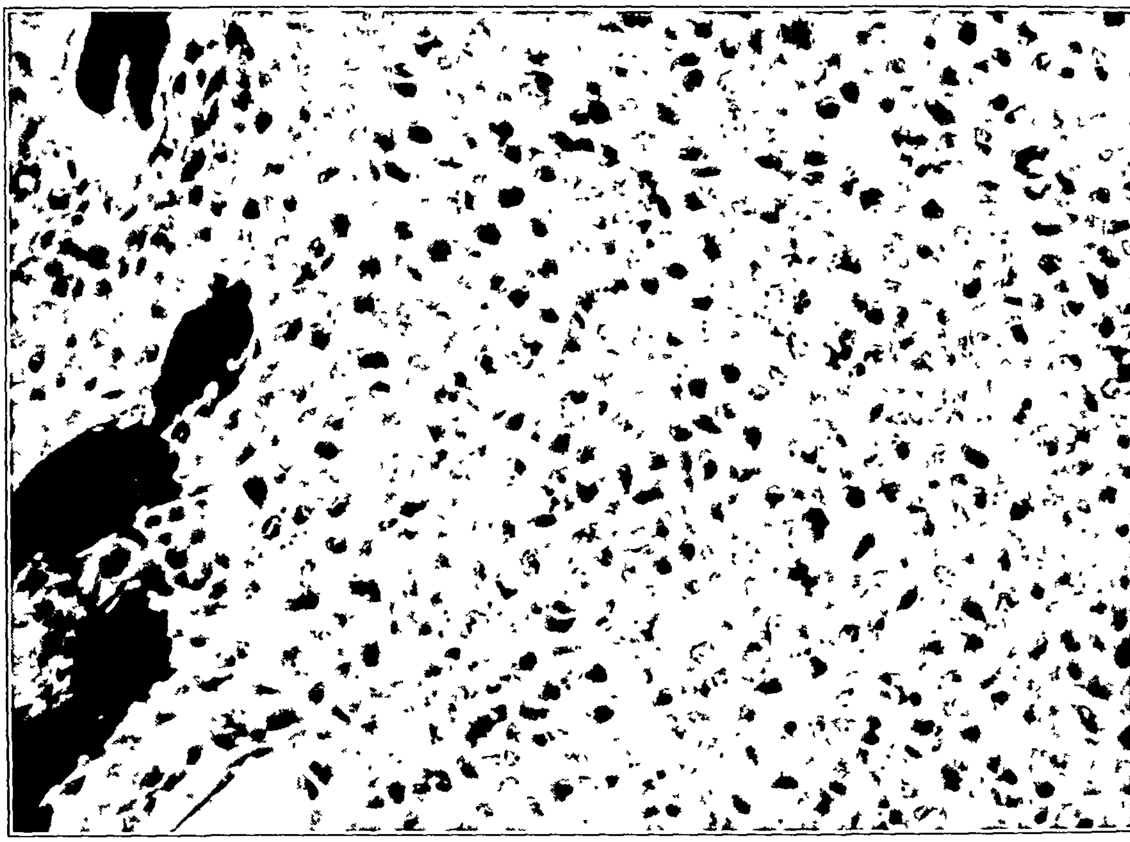


FIG. 1-F
Photomicrograph (×260) from periphery of tumor lobule shows closely packed immature chondroblasts.

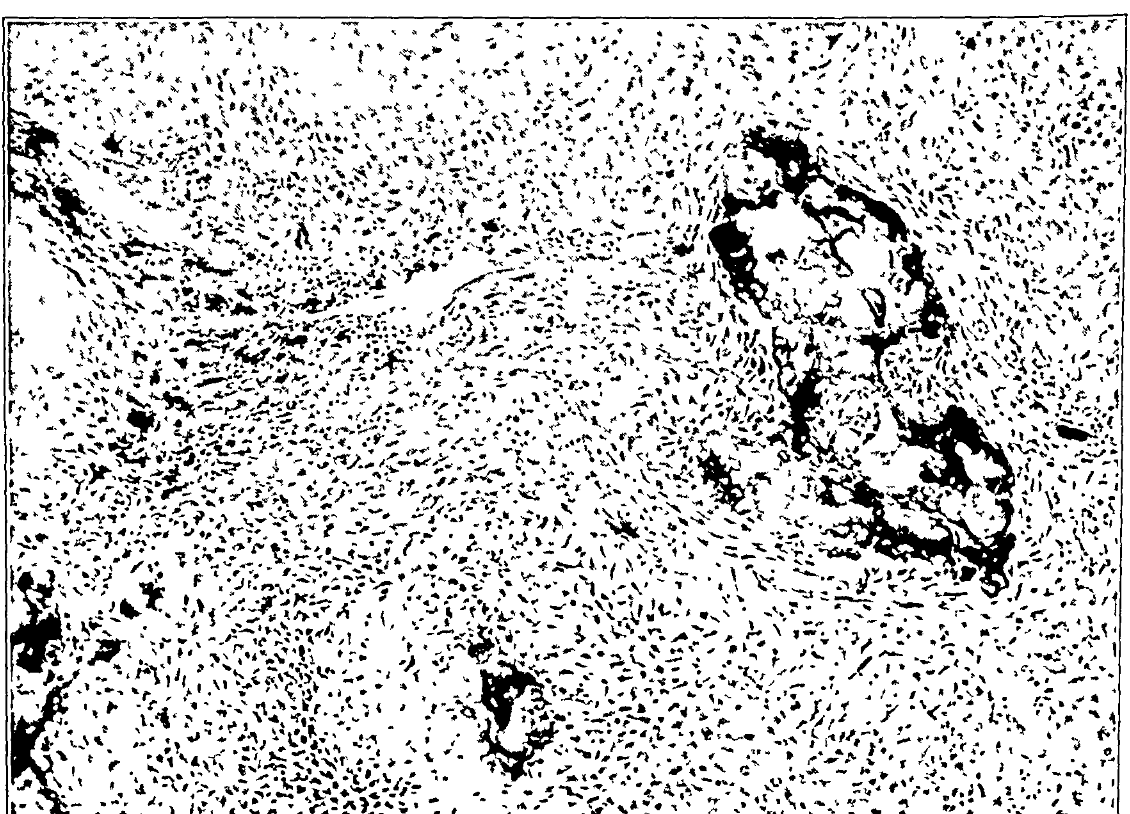


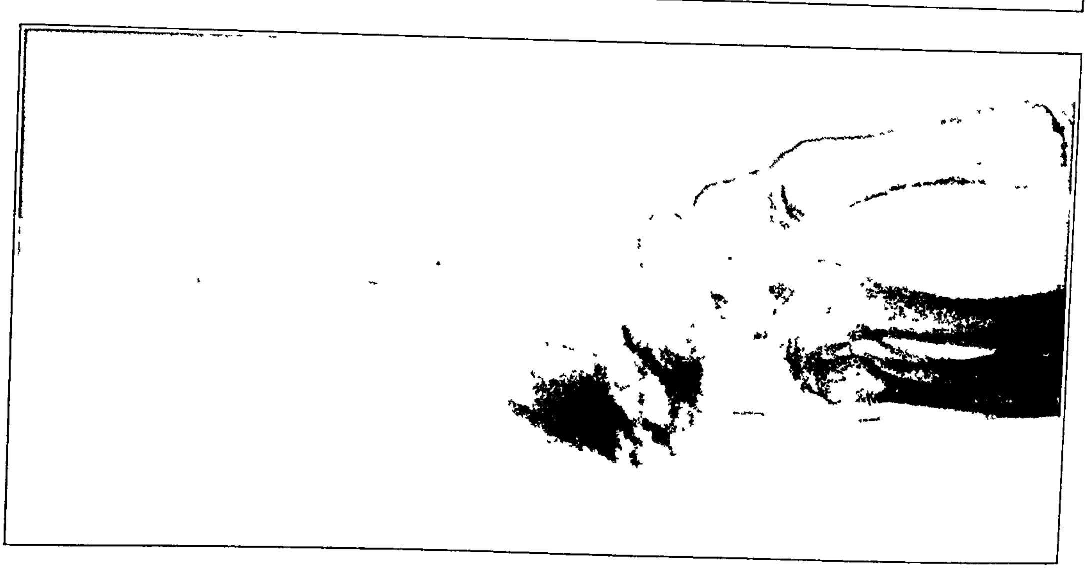
FIG. 1-G
Photomicrograph (×112) shows calcified tumor cartilage partly replaced by bone.

portals roentgen treatments each of 280 roentgen units in air filtered by 5 millimeters of copper and aluminum at 50 centimeters. Further therapy was administered during the next year so that a total of thirty-five treatments or 9800 roentgen units had been delivered to the surface. The patient remained well and without local symptoms until the onset of his present complaint. On examination, four years after the last roentgen exposure, there was evident on the anterior and lateral surfaces of the knee a band of pigmented, glazed, atrophic skin, six to ten centimeters wide, with telangiectasia but no ulceration. An anteromedial scar of 13.5 centimeters was well healed. The proximal end of the fibula beneath the telangiectatic skin was the site of a palpable non-tender mass. The dorsiflexor and peroneal muscles were paralyzed and the lateral aspect of the right leg and foot was hypalgic. The general examination was normal except for the findings in the right leg.

Roentgenograms (Fig. 1-B) showed irregular sclerosis at the site of the original tumor in the proximal tibial epiphysis, but no evidence of recent bone destruction. The shadow of the proximal 6 centimeters of the fibula was irregularly expanded by a mass of variable density, which partially obscured the bone. Laterally the mass had extended into the soft parts and medially it had encroached upon and narrowed the shadow of the lateral cortex of the tibia. In the distal 2 centimeters of the mass, there was marked increase in density in and around the fibular shaft. A diagnosis of sarcoma, primary in the proximal end of the fibula, was made. Roentgenograms of the lungs showed no evidence of metastasis.

FIG. 2-A

Case 2. Roentgenogram seven years after radium and x-ray therapy. The distal end of radius has been excised. There is sclerosis of distal end of ulna, but no evidence of tumor.



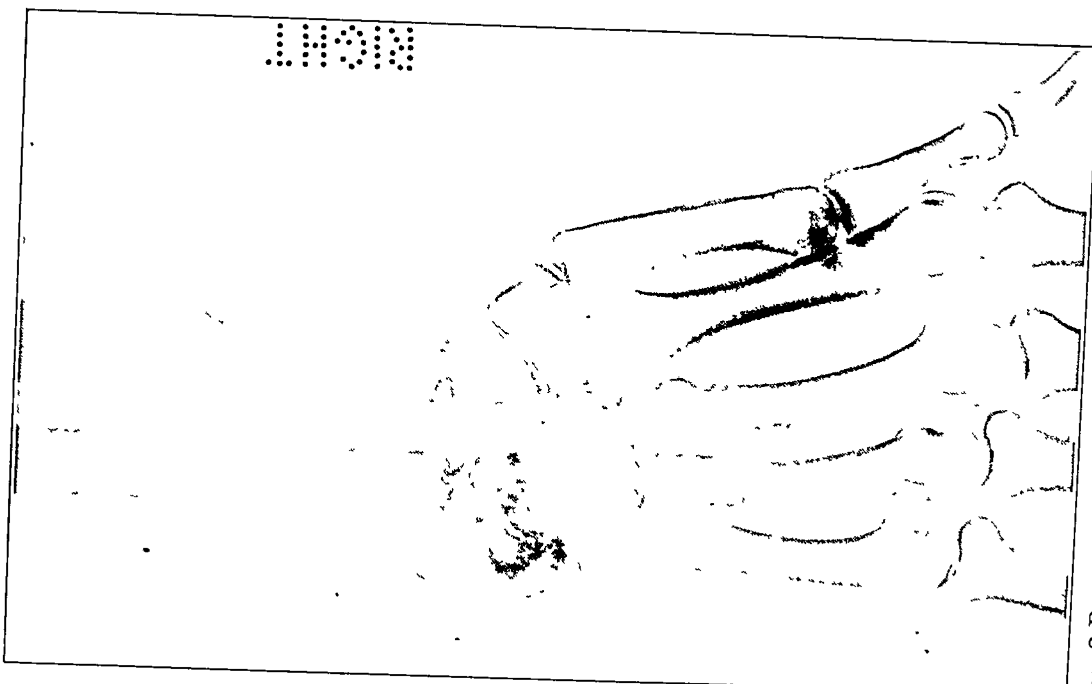


Fig. 2-B

Roentgenograms ten and a half years after irradiation. Position of hand has been corrected by osteotomy of ulna.

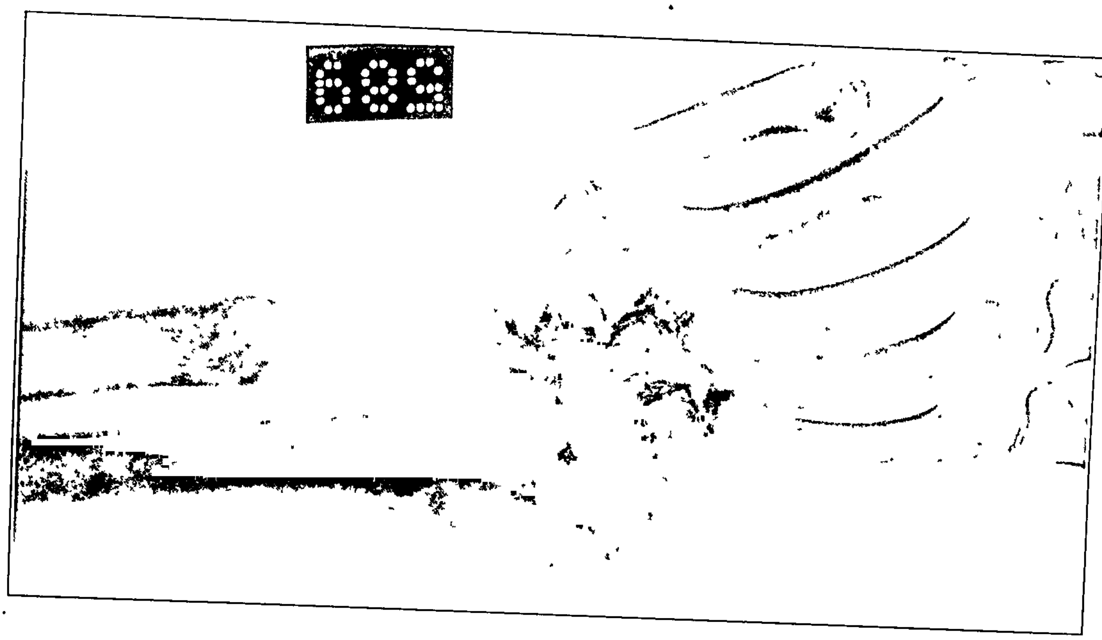


Fig. 2-C

Roentgenogram eleven years after irradiation, shows absorption of bone laterally at distal end of ulna.

On November 19, 1942, after the diagnosis of sarcoma had been confirmed by biopsy, a mid-thigh amputation was done. The wound healed without complication, and the patient was able to use an artificial limb eight weeks later. Ten months after the amputation, roentgenographic evidence of a metastatic tumor nodule appeared in the hilum of the right lung (Fig. 1-C). Two years after the amputation, the patient died. The amputation stump and the regional lymph nodes remained free of tumor recurrence and metastases.

Pathological Examination

The right lower extremity amputated in the mid-thigh showed the gross changes already described. On removal of the overlying soft parts, the proximal end of the fibula was found replaced by a tumor mass, measuring 8 by 6 by 3.5 centimeters. Mesially this mass encroached upon, but did not grow into, the lateral cortex of the tibia. Laterally and anteriorly it presented a lobulated surface. The peroneal nerve was incorporated in the mass. Frontal section (Fig. 1-D) through the tumor revealed a firm grayish-white mass which distally was bony hard, while proximally there were islands of bony density with surrounding firm glistening tissue of rubbery consistency. A roentgenogram of a slice through the tumor (Fig. 1-E) demonstrated almost complete destruction of the proximal 3 centimeters of the fibula. Irregular blotchy shadows were seen throughout the tumor. There was marked increase in density of the proximal end of the remaining shaft, and shadows of new bone formation radiated from it.

The proximal end of the tibia showed a depression anteriorly in the region of the operation done on the original benign tumor. Frontal section of this bone revealed no evidence of tumor tissue. Except for sclerotic margins, the defect had filled in with normal cancellous bone. The femoral and saphenous veins showed no evidence of tumor thrombi.

The section prepared from a frontal slice of the entire tumor of the fibula showed its irregular, lobulated structure. The peripheral portions of these lobules were composed of closely packed round or stellate cells, while centrally the cells were larger and the intercellular matrix more abundant (Fig. 1-F). Calcification and immature ossification were seen in the fibrous stroma between lobules and in the central areas of degeneration (Fig. 1-G). In the distal portion of the tumor, more immature ossification radiated from the fibular shaft.

Diagnosis: Chondrosarcoma, primary in the proximal end of the fibula.

FIG. 2-D

Photograph of resected distal three inches of ulna shows tumor mass projecting from lateral surface.

CASE 2. M. K., a female, when twenty-two years old, noted a painful swelling on the radial side of her right wrist. A diagnosis of benign giant-cell tumor was made with the aid of roentgenograms and tissue biopsy. Treatment by three applications of radium was given and later the patient received roentgenotherapy from several doctors. Ulceration and infection of the site occurred. A draining sinus necessitated removal of necrotic bone after three years. The total amount of irradiation by radium and by roentgenotherapy is unknown, but on entry here at the age of twenty-nine years the skin of the distal third of the forearm was atrophic, exfoliative, pigmented, and adherent to the underlying structures. The hand at this time deviated radially almost at a right angle to the forearm, due to loss of the distal portion of the radius (Fig. 2-A). There was sclerosis of bone in the distal end of the ulna, but no definite evidence of tumor Osteotomy of the distal end of the ulna was done to correct the hand position, and an osteoperiosteal bone graft was added. A roentgenogram (Fig. 2-B) three years after the operation showed the deformity corrected. Four years after the osteotomy of the ulna—that is, eleven years after radium and roentgenotherapy—the patient noted a small tender swelling over the distal end of the ulna. The roentgenogram (Fig. 2-C) then showed an area of rarefaction laterally in the distal end of the ulna. Excision of the distal three inches of the ulna was done and the defect bridged by a tibial-bone transplant Healing occurred, although there was superficial ulceration of the damaged skin. Ten years after the excision of this second tumor, there was no evidence of local recurrence or metastasis.

Pathological examination of the excised ulnar segment showed near its carpal end a firm mass, 2 by 1.5 centimeters, projecting from its lateral surface (Fig. 2-D). A microscopic section made through the entire specimen showed sclerotic bone of the ulna replaced by a densely cellular tumor The cells were mainly

spindle cells with abundant collagen formation. A moderate number of multinucleated cells were present. Mitotic figures were easily found. In the central portions of the tumor, there was myxomatous degeneration, and tumor cartilage was observed (Figs. 2-E and 2-F).

Diagnosis: Fibrosarcoma with tumor cartilage.

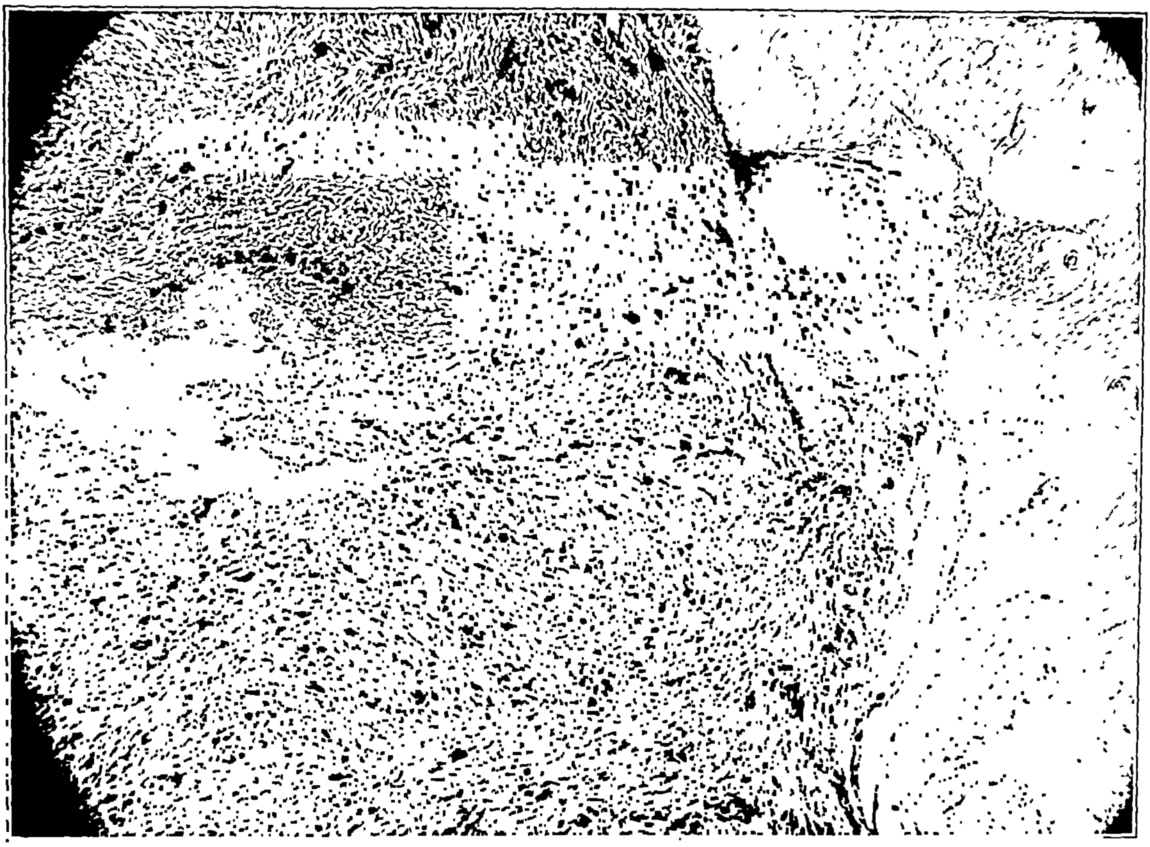


Fig. 2-E
Photomicrograph (×44) shows fibroblastic tumor which replaced bone.

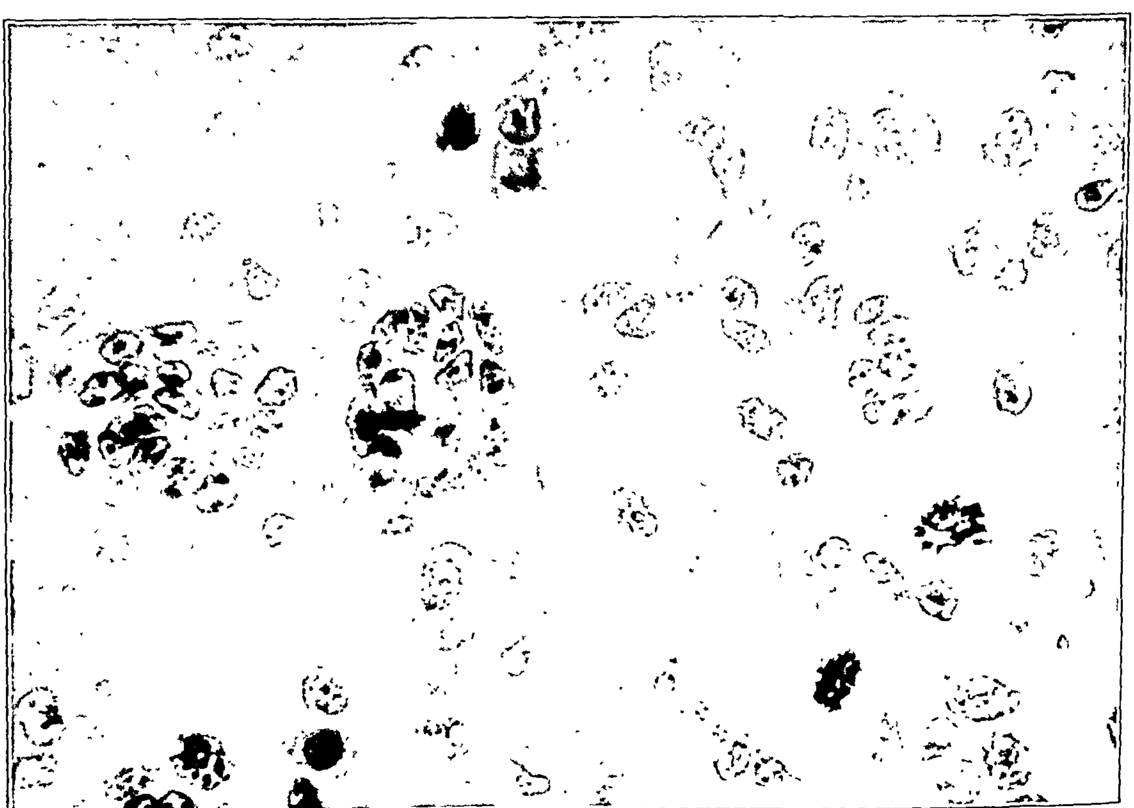


Fig. 2-F
Photomicrograph (×960) shows multinucleated cells and mitotic figures.

CASE 3. D. W., a woman of forty-nine, had had a radical mastectomy for carcinoma of the right breast twelve years before she was admitted to the Clinics in October 1943. Except for slight swelling of the right arm and temporary disability, she had had no postoperative difficulty. Four weeks after the mastectomy, roentgen-ray treatments were begun through anterior and lateral portals over the right chest and shoulder. Treatments were completed in September 1931. Accurate information on the amount of roentgenotherapy is not available. The patient estimates that she received twelve treatments during an interval of three months. She noted no skin alteration during or after therapy. She remained well until January, 1943—that is, eleven years after the last x-ray treatment—when she noted pain on pressure over the right side of the chest. Roentgenograms in May 1943 (Fig. 3-A) showed replacement of the anterior end of the right seventh rib by a mass of irregular density. The lung fields show no evidence of metastases. A total of 3000 roentgen units was given to the rib tumor in fifteen daily treatments of 200 roentgen units with 0.5 millimeters of copper.

When the patient came to the University Clinics in October 1943, examination showed a well-healed scar of the radical mastectomy. Anteriorly and laterally over the right side of the chest there was irregular brownish pigmentation, presumably from the recent roentgenotherapy. Near the costrochondral junction of the seventh rib a tender enlargement was palpable. No lymph nodes could be felt in the axilla or in the neck. Slight oedema was present, but no disability of the right arm.

On November 1, 1943, an oblique 20-centimeter incision was made over the anterior portion of the right seventh rib. The sixth, seventh, and eighth ribs were freed to the osteochondral junction, were cut posteriorly, and the pleural cavity was opened. A mass projecting on the posterior surface of the seventh rib could be palpated near the junction of the rib and its cartilage. The sixth, seventh, and eighth ribs with adherent portion of diaphragm were excised. The wound healed without complication. Six months later examination and roentgenograms disclosed no evidence of local recurrence or of metastasis.

Pathological Examination

The specimen (Fig. 3-B) of the seventh rib was 15 centimeters in length and included 1 centimeter of the

FIG 3-A

Case 3. Roentgenogram of chest eleven and a half years after right mastectomy and x-ray therapy shows right seventh rib replaced anteriorly by a mass with irregular shadows of new bone

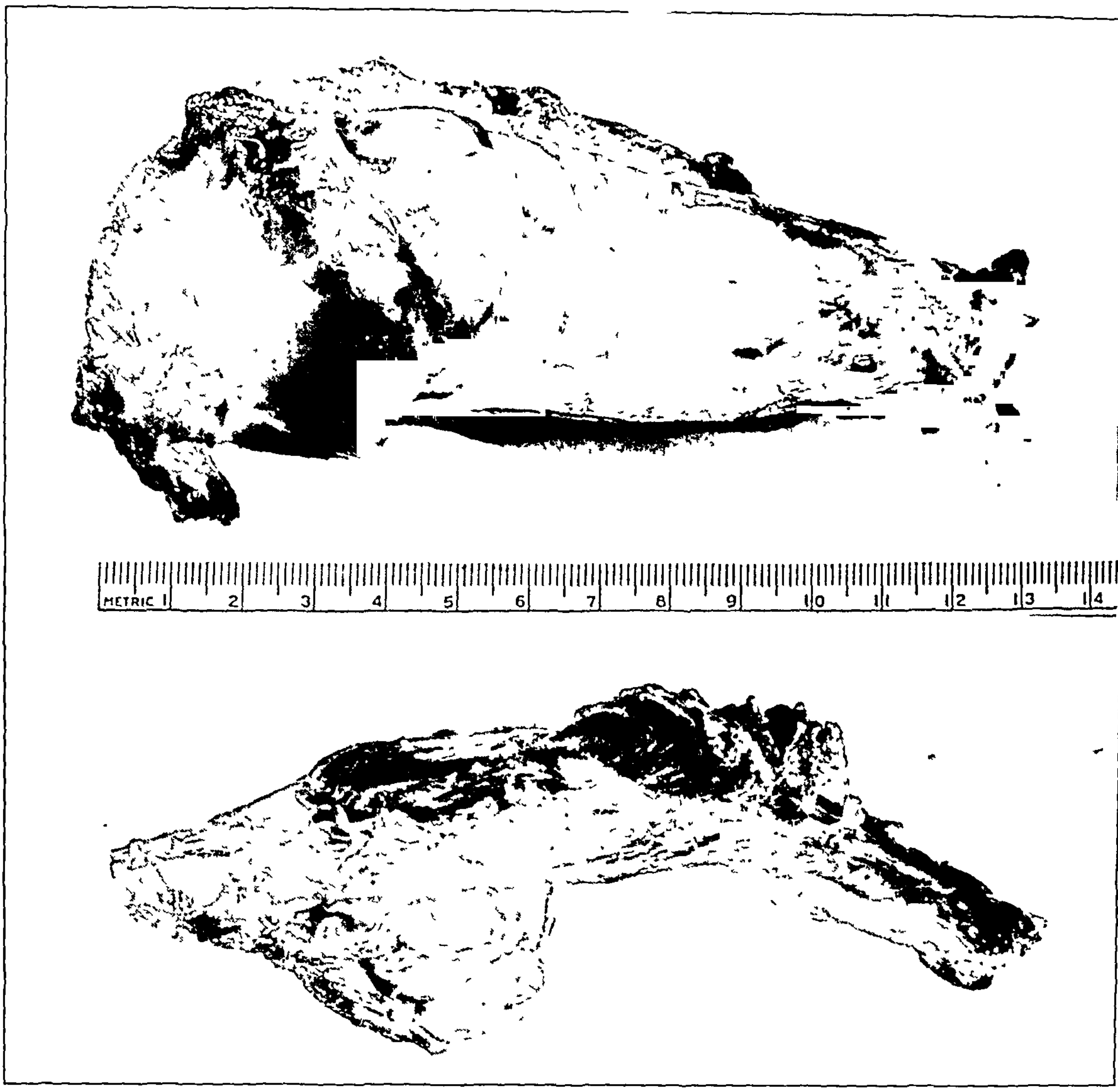


FIG. 3-B
Superior and lateral surfaces of resected seventh rib. Pleural surface shows subpleural nodule and attached diaphragmatic muscle.

FIG. 3-C
Photograph of microscopic section through entire specimen.

costal cartilage. The distal 9 centimeters was enlarged by a firm mass which projected 0.5 to 1 centimeter from the lateral surface. The mesial surface was thickened and broadened along its entire length. At the anterior end a firm mass, 2 by 4 by 4 centimeters, projected from the pleural surface and was adherent to a portion of the diaphragmatic musculature.

A microscopic section was prepared through the entire length of the involved rib (Fig. 3-C). This demonstrated the intramedullary and subperiosteal extent of the tumor. The subpleural nodule with ad-

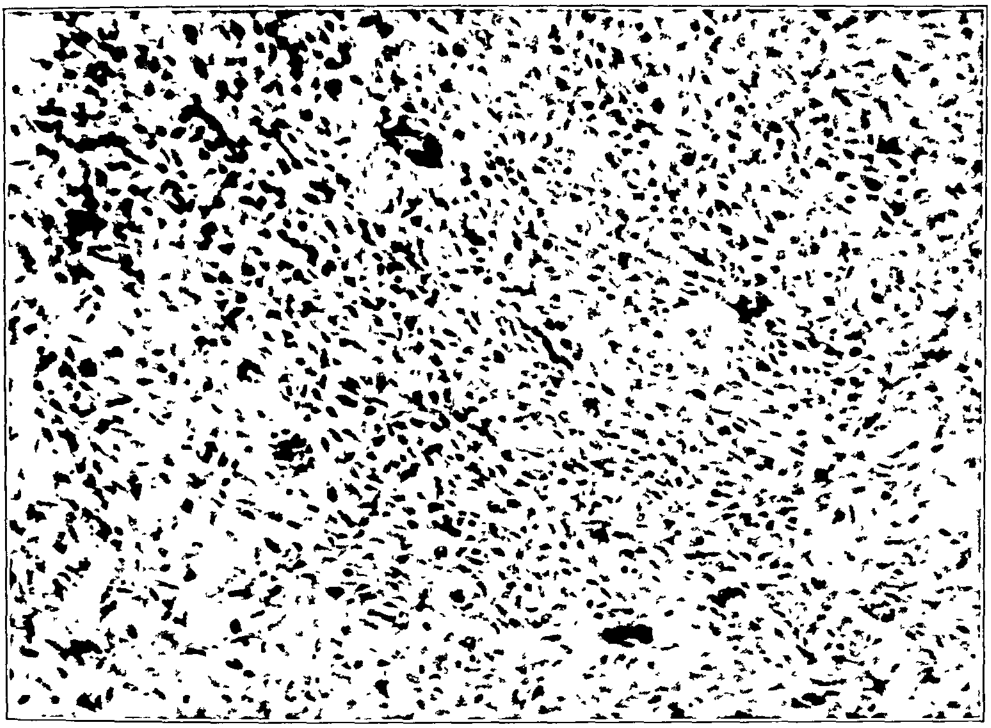


Fig. 3-D

Section (×200) from periphery of subpleural nodule shows closely packed round and stellate chondroblasts and multinucleated cells.

herent muscle was seen near the osteochondral junction. The characteristic tumor cells were best seen in this subpleural nodule, where peripherally they were small and flattened with little intercellular substance (Fig. 3-D). Centrally the cells were larger and stellate, and there was much intercellular hyaline matrix which showed granular calcification and ossification (Fig. 3-E). Other subperiosteal regions showed essentially the same picture. The cortices of the rib could be identified. Most of this bone was necrotic, as a result either of the recent roentgenotherapy or of interference with the blood supply by the tumor. Neoplastic bone had in many areas been laid down on the surface of old bone trabeculae (Fig. 3-F).

Diagnosis: Chondrosarcoma, primary in the seventh rib.

DISCUSSION

The three tumors here reported are regarded as sarcomata, produced by irradiation therapy for earlier neoplasms in the same regions. There is the possibility that they represent recurrence or metastasis of the original tumors. In Cases 1 and 2 the initial lesions were considered to be benign epiphyseal tumors. Apparently surgical operation and irradiation effected a cure of this disease in each case. Against the idea that the subsequent sarcoma represents a regional recurrence or latent metastasis of the primary tumor is the long period before sarcoma was evident. In Case 1, seven years and in Case 2, eleven years elapsed between eradication of the benign tumor and appearance of sarcoma. Also against local recurrence is the fact that in each case the sarcoma developed not at the site of the original tumor but in previously normal bone. Latent metastasis from the original growths can hardly be the explanation, since the second tumors are clinically and histologically different from the original ones. Moreover, irradiation sufficient to destroy the first neoplasm should have destroyed any metastases in the same field.

Sarcomatous change in benign giant-cell tumor has been described. Evidence of such malignant change has usually been obvious within one or two years at the site of the original tumor. The possibility may be noted here that so-called late malignant degeneration of benign giant-cell tumor treated by irradiation may represent in some cases sarcoma induced by irradiation.

It is unlikely that Cases 1 and 2 are instances of malignant transformation of giant-cell tumor.

FIG. 3-E

Section (×200) from central portion of nodule shows necrotic cartilage with calcification and ossification.

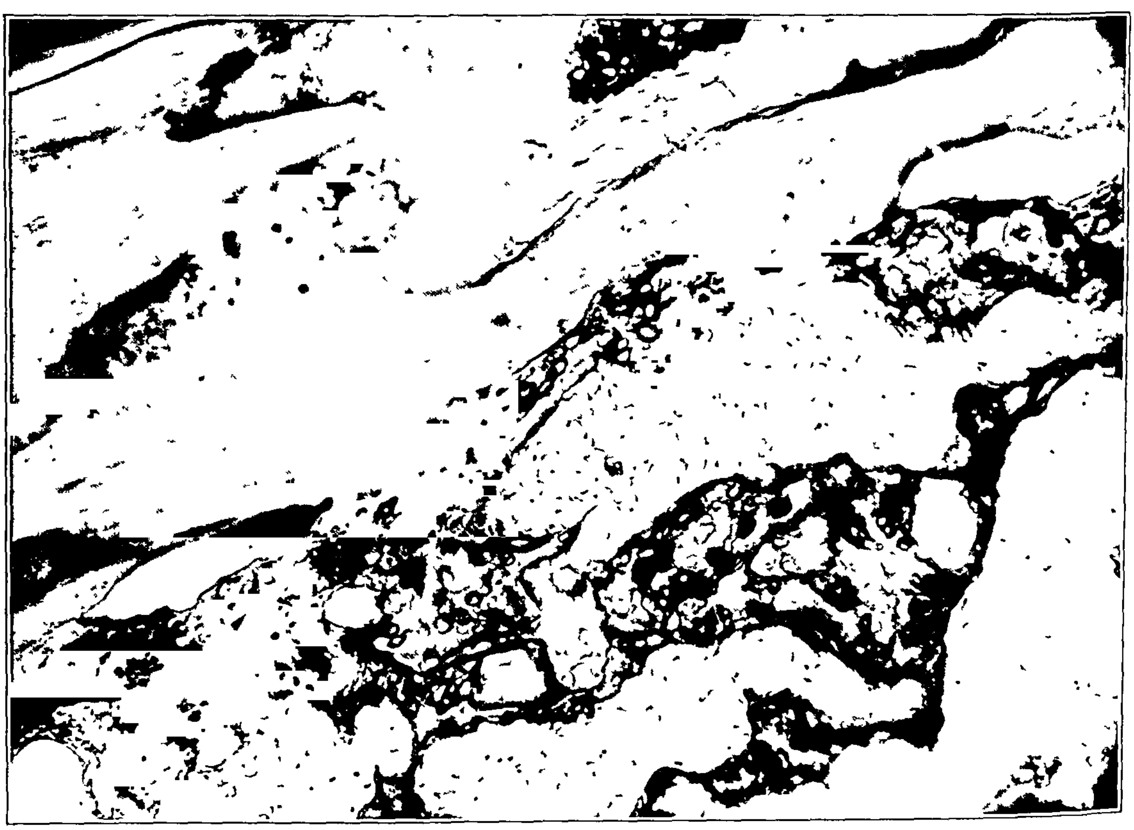


FIG. 3-F

Section (×100) from medulla of rib shows necrotic old bone trabeculae with ossifying cartilaginous tumor.

In Case 3, no question of regional recurrence or latent metastasis can be raised, because the primary tumor was carcinoma of the breast and the late rib tumor a chondrosarcoma. There can be some doubt that the postoperative irradiation caused the rib tumor, since apparently relatively little irradiation was used. Also the ribs are a common site for chondroma and chondrosarcoma, which may grow slowly and not produce symptoms for a long time. However, chest roentgenograms made at the time of mastectomy, though not now available, were reported as normal. It is probably more than coincidence that chondrosarcoma developed in a rib within the field irradiated for carcinoma of the breast.

The presence of chronic infection in all the early cases of roentgen sarcoma of bone led most authors to the conclusion that irradiation of chronically inflamed tissue was responsible for tumor formation. Lacassagne and others stressed also the importance of infection and chronic irritation in experimental production of irradiation sarcoma. Although Schürch and Uehlinger, and later others, showed that irradiation by roentgenotherapy or radium alone produced bone sarcoma in a fair percentage of animals, there have been few reported clinical cases. Martland's cases of poisoning by radium ingestion and Nørgaard's case of bone sarcoma after the treatment of chronic arthritis by intra-articular radium chloride are the only recorded irradiation sarcomata of bone where infection was not present in the irradiated field. In this present report, Case 1 and Case 3 showed no infection. In Case 2 there was local bone infection, following ulceration of the skin, due to roentgen and radium therapy. This infected tissue was never irradiated, and the roentgen sarcoma arose in bone which had not been infected.

It is true that occasionally malignant tumors develop in chronically infected bone, not subjected to irradiation. These tumors, however, are usually carcinomata, developing in chronic ulcers or in epithelized sinus tracts. Sarcoma formation in chronically infected bone not exposed to irradiation is extremely rare. Kaufmann mentions one such case, but it is open to question.

Most studies on the effect of irradiation upon the skeleton have been concerned with alterations in hematopoietic marrow and with disturbances in epiphyseal cartilage. The changes in osseous tissue have received less attention. Phemister showed that radium implanted in bone produces extensive aseptic necrosis of regional bone. Replacement of the dead by living bone occurs more slowly than in other forms of aseptic necrosis, and hence fractures are apt to occur. Dense fibrous scar eventually occupies the marrow spaces. Whether sarcomata develop from the fibrous scar or from damaged reticulo-endothelial cells is not known.

One of the most interesting facts about roentgen or radium-induced sarcomata of bone is the large proportion of cartilage-forming tumors. This is true of sarcomata produced in experimental animals, as well as in human beings. Unfortunately the histological description of some of the earlier cases is not detailed enough to permit of classification as to histological type. Nevertheless, of the twenty-four cases recorded, nine are undoubtedly cases of chondrosarcoma. Cases 1 and 3 of this report are typical chondrosarcoma. Case 2 shows myxomatous degeneration and cartilage formation, but the greater part of the tumor is a typical fibrosarcoma. Such a tumor is difficult to classify accurately. The reason for the predominance of sarcomata of cartilaginous nature is not known. It may be that undifferentiated mesodermal cells or reparative scar tissue, when stimulated to neoplastic growth by irradiation, take on cartilage-forming ability.

Roentgenotherapy was used in eighteen of the twenty-four recorded cases of irradiation bone sarcoma. In all of these the total irradiation was great. Many reports do not record the amount accurately, but from the descriptions of changes in the skin and other soft parts it is evident that severe tissue damage was produced. The roentgenotherapy in all of them was administered in repeated doses, spaced over one to five years. In Case 1 of this report 9800 roentgen units were delivered to the surface in fractional doses during

one year. The proximal end of the fibula, it can be estimated, received approximately 80 per cent. of that dose. The secondary radiation within bone may increase the effect within and about that tissue. In Case 3 roentgenotherapy produced no noticeable skin alteration. Practically all that was administered can be assumed to have been delivered within the ribs, since radical mastectomy had removed all overlying musculature. It may be that bones rich in hematopoietic tissue and reticulo-endothelial cells are more prone to develop sarcoma than are bones which have a greater proportion of fatty marrow. It may be also that predisposition of the individual to neoplastic growth is a factor in development of irradiation sarcoma. Warren and Ehrenreich have shown in cases with multiple tumors that there exists an individual susceptibility to cancer.

The time required for development of sarcoma after irradiation of bone is long. In the cases in the literature, the shortest interval was three years and the longest eleven years. In the three cases added here, sarcoma was recognized four, eleven, and eleven years respectively, after the final exposure to irradiation. The median for all reported cases is six years.

SUMMARY AND CONCLUSIONS

1. Twenty-four cases of bone sarcoma which followed x-ray or radium irradiation of bone are reviewed. All except six of these occurred in association with chronic joint infection.
2. Three cases are added which are regarded as bone sarcoma, resulting from irradiation of bone for earlier independent tumors. Two are chondrosarcoma, and one is fibrosarcoma with tumor cartilage.
3. In all cases except one, the amount of irradiation was large and was administered in fractional doses over a long period.
4. The interval between irradiation and recognition of irradiation-produced sarcoma is long. The median time in reported cases is six years.
5. Chondrosarcoma occurs more frequently among irradiation-produced sarcomata than in other bone tumors.

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TREATMENT OF BENIGN GIANT-CELL TUMORS BY RESECTION OR EXCISION AND BONE GRAFTING *

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The complete excision of benign giant-cell tumors results in cure. The site and extent of the tumor are important factors when deciding on the type of treatment. Since such tumors are osteolytic in nature, fracture is common. This is especially true in weight-bearing bones. In the majority of cases, the tumor occurs in the region of a joint. It is the purpose of this presentation to discuss the experience with resection and with excision and bone grafting for benign giant-cell tumor at the Mayo Clinic. Although excision of the tumor without bone grafting may result in a cure, ossification of the blood-filled cavities is slow and convalescence is prolonged unduly. In certain cases, complete excision of the tumor and bone grafting result in a more rapid cure without deformity or disability, and restore strength and function of the extremity in a shorter time.

Because of the size and site of some benign giant-cell tumors, irradiation therapy is the only treatment that can be employed. Interesting cures have resulted from the use of roentgenotherapy alone. In Case 8, reported later in this paper, such a result was obtained. A combination of surgical treatment and roentgenotherapy may be employed, but this treatment is associated with a certain amount of danger (Case 7); and surgical treatment only, wherever it is possible, is preferable. Preoperative irradiation may produce damage of tissue and atrophy; I have observed patients so treated, in whom the operative scar broke down, an ulcer formed, and the graft was lost. One must keep an open mind as to the relative value of the methods of treatment and employ that which, in his experience, has proved to be the best in the individual case.

The evaluation of any type of treatment depends on a correct diagnosis, on judgment in the selection of patients, on skill in carrying out the treatment, on a careful review of the history, on the clinical, roentgenographic, pathological, and surgical findings, and on the patient's progress for several years afterward. In studying a series of forty cases of this type of tumor, in which excision of the tumor and bone grafting were performed during a period of thirty-one years, 1913 to 1943 inclusive, I have endeavored to adhere to these criteria.

HISTORY

In 92 per cent. of the forty cases, the patients were between ten and fifty years of age; the average age was 28.7 years. The youngest patient was eight years of age, and the oldest was sixty-three years. A history of a single injury was elicited in twenty-one cases (52 per cent.), and multiple injuries had occurred in two cases (5 per cent.). In four cases (10 per cent.), it was definitely stated that injury had not occurred; and in thirteen (32 per cent.), trauma was not mentioned in the history. In thirty-two cases (80 per cent.), symptoms had been present for less than three years; in twenty-three cases (58 per cent.), symptoms had been present for less than one year; and in eight cases (20 per cent.), symptoms had been present for three years or more. The average duration of symptoms before operation was 23.5 months. Treatment prior to consultation and operation at the Clinic had consisted of immobilization, diathermy, elimination of foci of infection, arthritis vaccines in five cases (12 per cent.), aspiration in six cases (15 per cent.) in two of which irradiation also had been employed, irradiation alone in four cases (10 per cent.), excision and

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irradiation in one case (2.5 per cent.), and excision and bone grafting in two cases (5 per cent.). In two (5 per cent.) of the cases, a diagnosis of sarcoma had been made and amputation had been advised.

DIAGNOSIS

Although the diagnosis of benign giant-cell tumor usually can be made on the basis of the history and the clinical and roentgenographic findings, an occasional error may occur. Microscopic examination is more reliable, and has seldom been in error. Although Herendeen admitted that an error may occur in the roentgenographic diagnosis, he expressed the opinion that routine biopsy is unnecessary, if the clinical history and the physical and roentgenographic findings are characteristic. However, in my experience, these so-called characteristic clinical and roentgenographic features are untrustworthy. Herendeen said further that, if the diagnosis cannot be made without microscopic examination, it is not uncommon to find that the microscopic findings are as uncertain as the roentgenographic findings. Furthermore, he said that biopsy may result in infection, dissemination of tumor cells, and acceleration of growth of the tumor, owing to breaking down the natural barrier around it. Operations which are performed with the aid of a tourniquet, such as resection of the involved portion of bone and complete excision of the tumor by curettage followed immediately by cauterization, and microscopic examination of frozen sections have practically eliminated such complications. There are some cases in which the pathologist has not been given the true tumor tissue, or he has been given such small portions of tissue that an accurate diagnosis was impossible. A punch biopsy is useful in those cases in which the tumor is situated in inaccessible regions and in cases in which exposure is dangerous. Although this procedure is employed at times at the Clinic, it is not used routinely. Close cooperation between the pathologist and surgeon at the time of the operation leads to the correct diagnosis and prompt treatment. The differential diagnosis of benign giant-cell tumor and malignant giant-cell sarcoma cannot be made on the basis of roentgenographic interpretation alone. Adequate exposure and the removal of a block of tissue will enable the surgeon and the pathologist to examine the gross specimen and obtain several sections for microscopic examination. Should there be any doubt that the lesion is benign, the wound should be closed and the pathologist given additional time. This sometimes is necessary in cases in which a previous operation has been performed, in cases where irradiation has been employed, and in cases in which the tumor is infected; it is rarely necessary if the patient has not received treatment previously.

SELECTION OF CASES

In the usual case in which excision and bone grafting are performed, the tumor is situated in an extremity; and, when such surgical procedures are carried out correctly, they give excellent results. After the roentgenographic examination has demonstrated the extent of involvement, and has excluded evidence of recognizable metastatic involvement in the thorax, the surgeon decides whether resection of the involved portion of bone or excision of the tumor with curettage and cauterization is indicated.

OPERATIVE PROCEDURE

Curettage of a giant-cell tumor should consist of complete excision; in order to accomplish this it is necessary to have a dry field and an opening large enough so that the size of the lesion can be determined and every particle of tumor tissue removed. Complete removal is necessary. Furthermore, the surgeon must select a bone from which the proposed graft is to be obtained; usually the graft is taken from the tibia, fibula, ilium, or from a sound portion of the involved bone. Although autogenous bone grafts are preferred, homogenous grafts have been used to fill huge defects. As hemorrhage may cause

serious complications in cases in which it is impossible to use a tourniquet, the surgeo should be prepared to pack the cavity. When such a procedure is necessary, a gauze pac impregnated with petrolatum and sulfathiazole is used, and the wound is sutured i layers. The pack may be left in place for a week, and the operation may be completed a the second stage. Massive resection of the involved bone is usually performed in case in which the tumor is situated in the radius, ulna, or fibula. When the tumor is large an involves the tibia or femur, large bone grafts are required. In such cases, the bone strut and shavings are generally obtained from the tibia.

The best results are obtained in cases in which the cavity is packed firmly with au togenous bone, and when complete rest is assured by immobilization of the extremity in plaster-of-Paris cast. In cases in which the tumor is situated in the region of the knee o the ankle, weight-bearing should be avoided until the roentgenographic examination dis closes sufficient deposition of bone to stand the stress and strain that will be required In those instances in which the articular cartilage is exposed, the use of supporting strut is advisable, and it is well to fill the interspaces with shavings and cancellous bone. An electric bone saw is employed for the removal of the struts, and a sharp chisel and curette are used to obtain shavings. After the

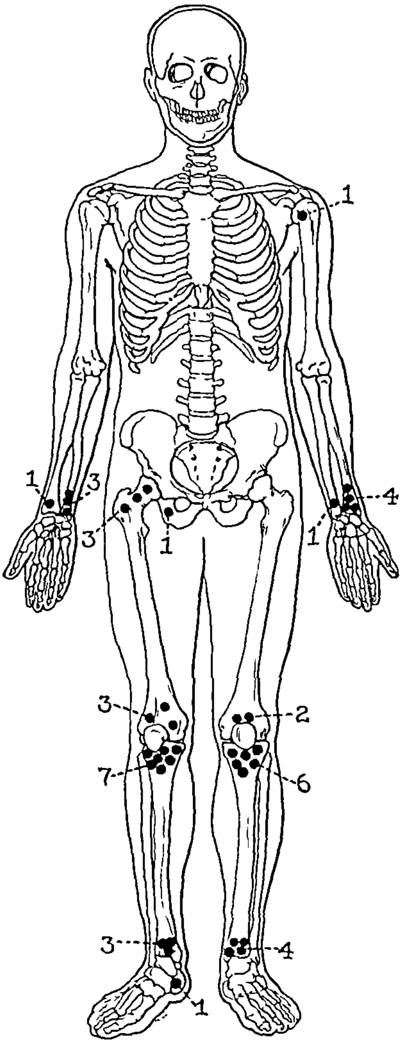

Fig. 1

Distribution of benign giant-cell tumors; the figures indicate the number of instances in which tumors occurred at the respective sites in a series of forty cases.

Fig. 2

Case 1. *a:* Benign giant-cell tumor expanding lower part of left ulna. *b:* Bone graft in position twenty-three years after operation. *c:* Photomicrograph (×85) of the tumor.

cavity has been packed with bone, the periosteum, whenever possible, is sutured; and the wound is closed snugly in layers. Bloody drainage should be avoided, as it may lead to infection or to osteomyelitis, in which case the grafts may be lost. Frank infection did not occur in any case in this series, although several patients had serous discharge for short periods, or ulcers in incisions as a result of previous irradiation. In the past, writers have emphasized the dangers of hemorrhage, shock, and infection. Modern aseptic surgery has to a large extent eliminated these complications.

RESULTS

In the twenty-six years from 1913 to 1938 inclusive, excision and bone grafting were performed in eighteen cases, and in the five years from 1939 to 1943 inclusive, these procedures were followed in twenty-two cases. In one patient, whose tumor was very extensive and cellular in type, and had recurred, an amputation was required. This patient is living more than five years after the onset of symptoms, and is wearing an artificial limb. Routine roentgenographic examination of the lungs did not disclose any evidence of metastasis in this series of cases. The sites of involvement in this series are shown in Figure 1.

Of twenty-six patients who had not undergone a previous operation, twenty-four obtained good functional results, and two required second operations. One of these patients required an amputation; the other was operated on elsewhere, and the result evidently was satisfactory. Of the four patients who had received only irradiation therapy of unknown degree before coming to the Clinic, all obtained good functional results. Of the three patients who had undergone an operation before they came to the Clinic, all obtained good functional results. Of three patients who previously had undergone some form of operation, and, in addition, had received irradiation therapy, also of unknown degree, all obtained good functional results.

Therefore, of the forty patients in this series, thirty-eight, or 95 per cent., obtained good functional results, and two, or 5 per cent., did not.

Three of the forty patients have died. One of these died suddenly of cerebral hemorrhage, one year after operation. One died of chronic inflammation of the intestine and anaemia more than a year after operation, and the family physician said that there was no evidence of metastasis of the tumor. The third patient died suddenly, nearly seven years later, four days after the onset of pneumonia. The family physician reported no evidence of metastasis.

REPORT OF CASES

CASE 1. A woman, thirty years of age, came to the Clinic on June 30, 1913, because of aching pain and swelling of the left wrist of two years' duration. There was no history of trauma, and she had had no previous treatment. On July 4, 1913, the lower end of the left ulna was resected and a tibial bone graft was inserted. The pathologist reported that the lesion was a benign giant-cell tumor (Fig. 2, *a*). Twenty-three years later, the roentgenographic examination showed that the bone graft was in good position and that union had occurred. In March 1944, or thirty-one years later, the patient reported that she had good function of her arm.

CASE 2. A woman, twenty years of age, came to the Clinic on April 25, 1927, because of pain, swelling, and local heat, which had been present in the right leg for nine months. There was no history of trauma. The severity of the symptoms had increased gradually, and she had been told she had a cancer of the bone. Clinical and roentgenographic examination revealed a giant-cell tumor of the upper part of the right tibia (Fig. 3, *a* and *b*). The lesion had destroyed practically all of the upper part of the tibia. On April 27, 1927, soft tissue was removed by curettage, and numerous bone grafts from the flat internal surface of the tibia were placed in the cavity, after which the periosteum was sutured snugly. Then a cast was applied. The pathologist reported that the lesion was a benign giant-cell tumor. The convalescence was uneventful. Seventeen years later, the patient reported that she had not had any difficulty with her leg and that the function was good.

CASE 3. A woman, thirty-eight years of age, came to the Clinic on April 8, 1929, because of pain,

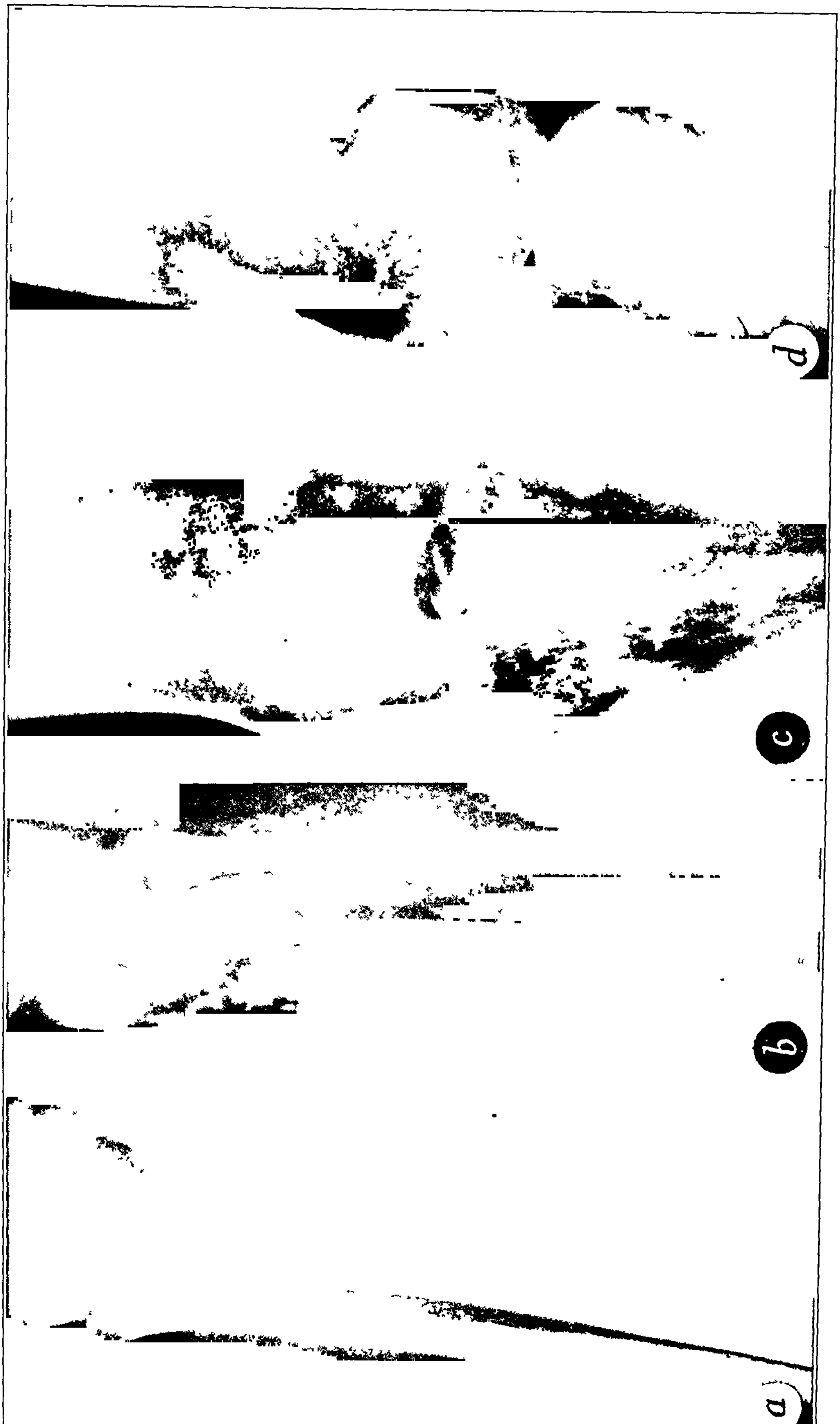

Fig. 3

Case 2. *a*: Anteroposterior roentgenogram of upper part of right tibia, showing benign giant-cell tumor; *b*: lateral roentgenogram showing tumor. *c* Anteroposterior roentgenogram, showing bone graft in position twelve and a half years after operation; *d* lateral roentgenogram made the same day.

swelling, and local heat of the left forearm of seven and a half years' duration. In the six weeks before she came to the Clinic, irradiation therapy had been employed twice, and operation had been advised. On April 11, 1929, operation revealed that the tumor had already broken through the cortex of the bone (Fig. 4, *a*). The tumor, which consisted of reddish jamlike material, was removed entirely by curette and chisel. A bone graft from the left fibula was fitted into the defect and was held in place with beef-bone screws (Fig. 4, *b*). A cast was applied from the fingers to the middle of the humerus. The pathologist reported that the tumor was a benign giant-cell tumor. The convalescence was uneventful and the patient returned home on the twenty-fourth day after operation. Six years and nine months later, she suddenly became ill with pneumonia, and died after four days. She had had good function and no trouble with her arm after the operation.

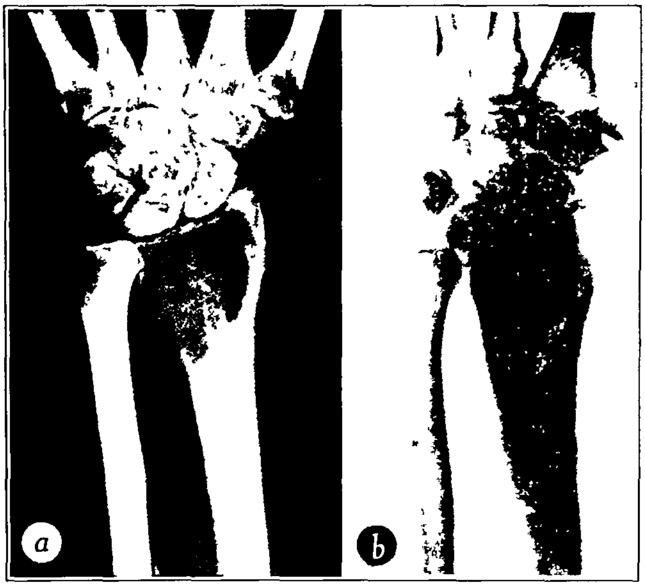

FIG. 4

Case 3 *a:* Benign giant-cell tumor that has destroyed the lower part of the left radius, and has extended into the soft tissues. *b.* Bone graft held in place with a beef-bone screw.

CASE 4. A woman, thirty years of age, came to the Clinic because of pain in the right hip of two years' duration. A diagnosis of arthritis had been made. Traction treatment had been employed, and she had used crutches. Later a tumor had been discovered. There was a history of trauma fifteen years before she came to the Clinic. Clinical and roentgenographic examination resulted in a diagnosis of giant-cell tumor or cyst (Fig. 5, *a*).

FIG. 5

Case 4. *a:* Benign giant-cell tumor, which has caused extensive destruction of the head and neck of the right femur. *b:* Appearance of involved bone three months after excision of the tumor and insertion of a bone graft.

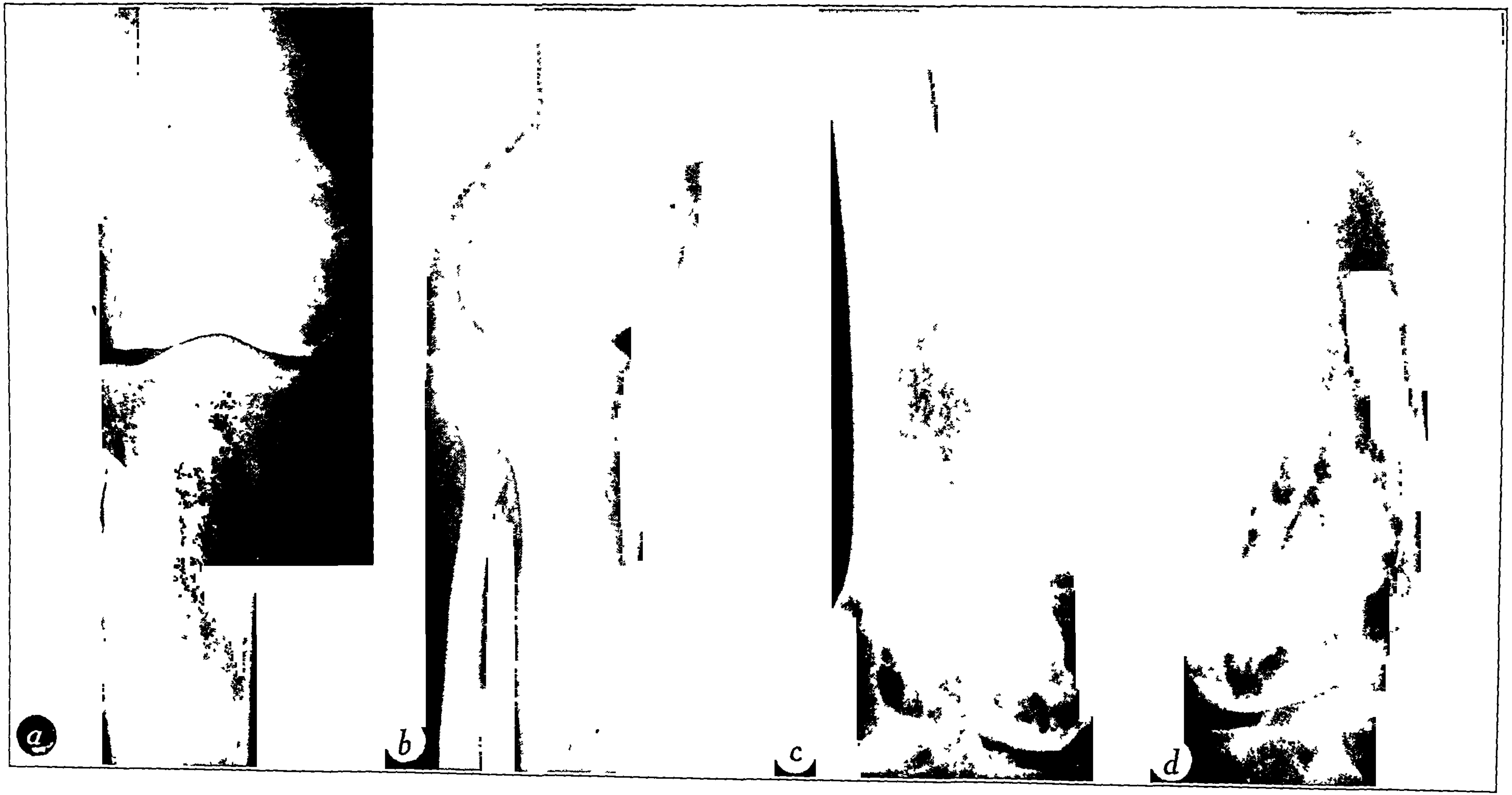

Fig. 6

Case 5. *a* and *b*: Anteroposterior and lateral roentgenograms, showing benign giant-cell tumor which has caused extensive destruction of lower part of right femur. *c* and *d*. Anteroposterior and lateral roentgenograms, showing bone grafts in position one year after operation.

Excision of the tumor and bone grafting were performed on June 28, 1938. Bleeding was controlled with hot packs, and the wound was swabbed with a solution of zinc chloride. Bone chips obtained from the right ilium and right tibia were packed into the cavity. A spica cast was applied. The pathologist reported that

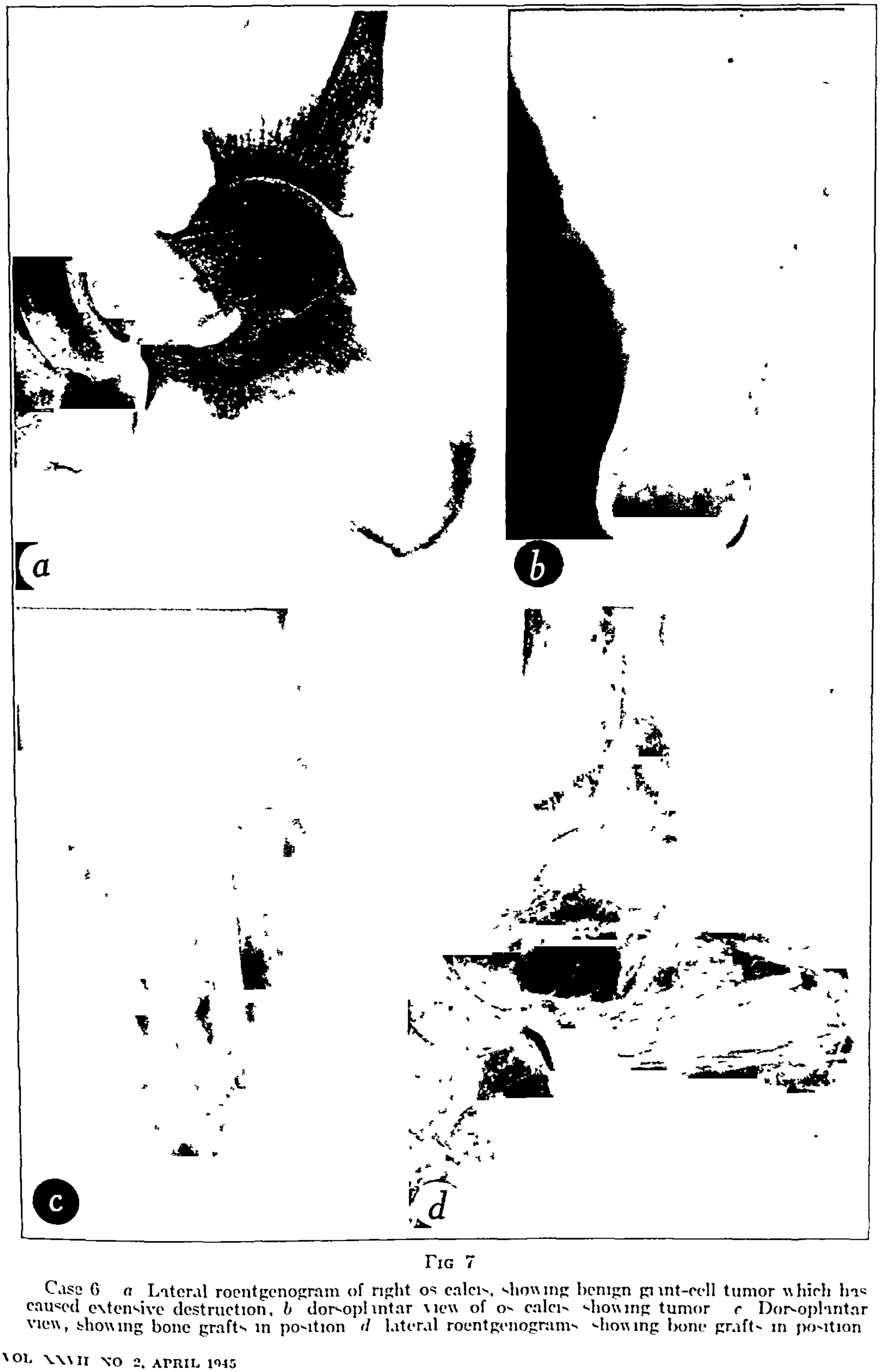

FIG 7

Case 6 a Lateral roentgenogram of right os calcis, showing benign giant-cell tumor which has caused extensive destruction, b dorsoplantar view of os calcis showing tumor c Dorsoplantar view, showing bone grafts in position d lateral roentgenograms showing bone grafts in position

FIG. 8

Case 7. *a*: Anteroposterior view, showing giant-cell tumor of the left ilium. *b*: Anteroposterior view, taken seven years after excision of the tumor and irradiation shows calcification of the tumor.

the tumor was a benign giant-cell tumor. More than five years later, the patient reported that she had good function and was working.

CASE 5. A woman, thirty-four years of age, came to the Clinic on January 28, 1939, because of swelling of the lower part of the right femur. The swelling had been present for one year. It had been associated with pain and a local increase in temperature. There was no history of trauma. A clinical diagnosis of giant-cell tumor was made (Fig. 6, *a* and *b*). The roentgenologist suggested the possibility of sarcoma. On January 30, 1939, the tumor was excised, and bone grafts were inserted. The periosteum was then sutured, and the wound was closed in layers. A cast was applied. The pathologist reported that the tumor was a benign giant-cell tumor. Convalescence was uneventful and the patient left the Hospital on the twenty-fifth day after operation. More than five years later, the patient said that the functional result was good.

CASE 6. A woman, forty-two years of age, came to the Clinic in October 1939, because of trifacial neuralgia. In the course of the examination she complained of occasional pain in the region of the right os calcis. A clinical and roentgenographic diagnosis of giant-cell tumor or cyst was made (Fig. 7, *a* and *b*). On November 1, 1939, the tumor was removed and bone grafts were inserted. The pathologist made a report of benign giant-cell tumor. Four and a half years later, the patient said that the function of the involved limb was good. She had no pain and was able to do her usual work.

CASE 7. A married woman, aged twenty-six years, admitted to the Clinic on June 8, 1937, complained of pain and swelling in the left buttock of four months' duration. A malignant lesion of the left ilium was suspected, and an exploratory operation was advised. On June 16, 1937, the tumor was excised; on examination of the tissue, the pathologist found that it was a benign, foreign-body, giant-cell tumor. The patient was given nine low-voltage roentgen treatments postoperatively, and calcification occurred.

In January 1941, the patient was delivered of a normal baby and complete calcification had occurred at the site of the tumor as shown in the roentgenogram (Fig. 8, *b*). Seven years after institution of treatment, the patient is in good health.

CASE 8. A man, twenty-nine years of age, was seen May 29, 1936, at which time he stated that about March 25 he had noticed soreness of his left shoulder, following exposure to cold. Pain had increased gradually, and he had been given physical therapy and roentgenotherapy for subdeltoid bursitis.

Roentgenograms of the left shoulder revealed a large area of destruction of the lateral aspect of the left scapula, just medial to the scapular neck. The roentgenologist made a diagnosis of metastatic malignant lesion. On June 16, 1936, the tumor was explored and tissue removed. The pathologist reported that the tissue came from a vascular giant-cell tumor. (This tissue has been re-examined recently by Dr. A. C. Broders who corroborated the diagnosis of benign giant-cell tumor.) It was the opinion of the surgeon that the tumor could not be removed unless a forequarter amputation was performed. Three low-voltage roentgen treatments were given. The patient had good motion of the left arm, and was free of symptoms in two months, at which time roentgenograms showed that the tumor was undergoing sclerosis. Six months later, further roentgenograms showed practically complete calcification of the tumor. The patient is living and well eight years after the biopsy and exploratory operation.

COMMENT AND SUMMARY

This paper is based on a series of forty cases of benign giant-cell tumor of bone, in which excision of the tumor and bone grafting were employed. The history, as well as the clinical, roentgenographic, and microscopic findings, and the follow-up data have been reviewed in all forty cases, and the diagnosis of benign giant-cell tumor has been confirmed. Massive resection and excision by curettage and cauterization appear to be safe methods of eradicating the tumor. The resultant cavities have been filled with autogenous bone, which stimulates rapid formation of bone, lessens the danger of collapse from fracture, and tends to prevent deformity and disability. Excision of the tumor and bone grafting is a safe procedure in properly selected cases, and it tends to prevent deformity and disability.

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DISCUSSION

DR. NICHOLAS S. RANSOHOFF, New York, N. Y.: I would like to congratulate Dr. Hatcher on his splendi presentation, and report another case. This is a case of which Dr. Gill knows, and which I think Dr. Moor saw and treated. The lesion resembled a bone cyst in the upper end of the humerus. The patient wa treated with massive doses of roentgenotherapy, and was operated upon by me last October. Much to m surprise, Dr. Jaffe's pathological report was fibrosarcoma of the bone. It has grown to large size. There i an extensive recurrence locally, but no axillary glands are involved. The chest x-rays have been reporte negative. We now wish to disarticulate the patient's arm, but his parents refuse to have it done. It wil be a pleasure to have Dr. Hatcher include this case with his.

DR. CARL E. BADGLEY, Ann Arbor, Michigan: As one reviews the literature on benign giant-cell tumo and giant-cell sarcoma, or the malignant variation of giant-cell tumor, much confusion is apparent. Various forms of therapy have been employed in the treatment of the benign tumor. In our own Clinic, the Department of Roentgenology in 1936 reported the treatment of forty cases of benign giant-cell tumor. The statistical report was of practically no value, because, as we classified these cases into various groups according to treatment, there were too few in each group to be of any value. It has been our opinion in the study of the cases we have followed since that time, that, in the treatment of giant-cell tumor, one must make up his mind whether he will employ roentgenotherapy or surgery. A combination of roentgenotherapy and surgery has given us poorer results than either alone. Eighty-six per cent. had good results by surgery alone; 85 per cent. by roentgen ray alone; 40 per cent. had good results from preoperative radiation, surgery, and then postoperative radiation, and 60 per cent. were failures from this treatment.

I want to emphasize that radiation following operation and the employment of a bone graft is a dangerous procedure. It may well prevent creeping substitution in the bone graft, and may interfere with healing.

I want to compliment Dr. Meyerding for the practical points in his talk. He has selected forty, or 28 per cent., of the giant-cell tumors, because they were benign and were treated by surgery. That gives us something to work with. A comparison of the figures from the Mayo Clinic and other clinics will give us ultimately a basis for selecting treatment. His success of 95 per cent. with surgery gives us something by which we can measure other forms of treatment.

Incidentally, the one failure we had—and I say this in justification of x-ray therapy—was a patient upon whom we operated, intending to do a bone graft. There was so much bleeding that we closed the wound, and finally convinced the X-Ray Department that they should give roentgenotherapy prior to surgery; under roentgenotherapy the patient recovered. That was an achievement with x-ray where surgery had failed.

DR. ALBERTO INCLÁN, Havana, Cuba: In my own experience the treatment of choice has always been complete resection whenever possible. Of course, the giant-cell tumor may be localized in places where we cannot use this type of radical surgery. In the cases where we have to preserve joint function, as in most of the cases Dr. Meyerding has shown us, we do a more or less complete excision, with bone grafting. We have had recurrence of the tumor twice after the use of this method. That is why I prefer complete resection, which has never been followed by recurrence in our cases. I have noticed that the patients treated by curettage and cauterization have shown the greatest number of recurrences. In the pathological examina-

tion of these recurrences we have found a malignant change in the histological aspect of the lesion, showing more or less marked signs of local malignancy in the stroma, such as hyperchromatism, mitosis, and sometimes increased vascularity of the stroma In other words there has been a definite change in the histological aspect of the original benign lesion, without the appearance of a true sarcoma In dealing with this type of case, I believe complete resection should always be done

In 1940 I published a paper reviewing thirty cases of giant-cell tumor, and I made it very plain that, even in these cases with local signs of malignant change, we did not have any metastases Since then, two of these cases have developed intrathoracic malignant tumors, which I am inclined to believe are metastatic lesions In both cases, these have become clinically apparent three years following local excision of a histologically proved giant-cell tumor

Dr C Leslie Mitchell Detroit, Michigan I was very much interested in Dr Hatcher's paper because I had reached the same conclusions A few years ago, a young girl, fourteen years of age, reported to the Clinic with a lesion of the lower end of the tibia, which on biopsy proved to be a giant-cell tumor She was given deep x-ray therapy, and about a year and a half later a lesion of the malleolar portion of the fibula developed Biopsy showed fibrosarcoma, and amputation was carried out Subsequently, metastatic nodes in the inguinal region were excised There has been no recurrence after seven years.

Subsequently we have had two other cases, similar in many respects, with malignant degeneration of a benign lesion following deep x-ray therapy One of these cases was a giant-cell tumor of the tibia, treated by Dr Peabody ten years ago by deep x-ray therapy The other one was a benign cyst of the humerus in a young girl, with development of sarcoma six months following irradiation

Dr C Howard Hatcher, Chicago, Illinois (closing) The cases reported by Dr Ransohoff and by Dr Mitchell are interesting ones and important, because of their rarity in American literature It is possible that some benign giant-cell tumors which have been reported to undergo malignant change are examples of sarcoma induced by therapeutic irradiation

It should be emphasized that the cases of irradiation sarcoma reviewed in this paper occurred mostly during a period when x-ray therapy was not so well controlled as to indications and dosage as it is now

How irradiation acts in producing malignant change in bone is unknown We do know that bony tissue undergoes avascular necrosis following intensive irradiation, and its repair is very slow It is probable that neoplasia occurs in either the marrow elements, or in the scar tissue which repairs the region damaged by irradiation

AN EVALUATION OF THE ESTIMATED PERCENTAGE OF GROWTH FROM THE DISTAL EPIPHYSEAL LINE

BY IRVIN E. HENDRYSON, M.D., PHILADELPHIA, PENNSYLVANIA

From the University of Pennsylvania, Graduate School of Medicine

The difficulty of estimating the expected growth of a long bone is stressed more and more by the increased interest in the problem of equalization of length of the lower extremities, particularly in considering the operation of epiphyseodesis. Digby measured a set of long bones, and established a standard scale of growth from distal and proximal epiphyseal lines. Bisgard and Bisgard substantiated his findings by experimentation with animals. Wilson and Thompson then applied the same figures clinically in an effort to determine the expected growth in an extremity. By estimating the percentage of growth from each epiphyseal line, they corrected the discrepancy by epiphyseodesis, as outlined by Phemister.

In explaining the basic principle involved, Digby postulated that:

". . . the nutrient canal always points toward the oldest part of the shaft of the long bone. *It is more accurate to say that the canal points towards the site which the oldest part of the bone would occupy were it not that the osseous tissue first formed is subsequently absorbed in providing the medullary cavity.* . . . The initial *point of ossification may be easily determined*, for it corresponds to that point in the centre of the medullary cavity which is reached by an imaginary prolongation of the nutrient canal. The site of initial ossification having been determined, it becomes easy to measure the precise lengths of bone which are formed from the two growing ends of the diaphysis. . . .

". . . and also in the case of the adult femur where, when two foramina are present (as not infrequently happens), the nutrient canals have different obliquities, so that when prolonged they converge on almost the same point in the medullary cavity."

Following this principle, Digby measured a set of long bones and established percentages of growth from distal and proximal epiphyseal lines which are now used (Table I).

The present study was undertaken primarily to evaluate this method of estimating growth. An attempt was also made to arrive at a standard mean of growth in a large series of cases, rather than to accept figures derived from one isolated set of measurements.

METHOD

1. *Material.* Measurements were made on fifty-four adult, human femora, selected at random from dried anatomical laboratory specimens. Of this number, forty-eight had a single nutrient canal, while six were discovered to possess two such canals. Because of this variation, they were considered separately, forming Group A and Group B in this report. Two femora from the new-born were secured and identical studies made on them; these form Group C.

TABLE I

A COMPARISON OF DIGBY'S SCALE WITH SPECIMENS SHOWING EXTREMES IN LENGTH AND PERCENTAGE GROWTHS FROM THE DISTAL EPIPHYSEAL LINE OF THE FEMUR

Specimen Number	Diaphyseal Length (*Centimeters*)	Growth from Distal Epiphysis (*Centimeters*)	(*Per cent.*)
103	45 5	32	70
94	34	24	70 5
14	43 5	34 5	79
24	37	18 5	50
Digby's Scale:	16 inches (40 centimeters)	11 inches (27.5 centimeters)	69 per cent.

2. *Mensuration.* In making the measurements of the femora it was decided that more exact data could be secured by making roentgenograms of the bones and measuring them. This procedure was carried out by first passing a small needle along the nutrient canal into the medullary cavity, and fixing it with modeling clay. The entire femur was then mounted on a cassette with clay so that roentgenograms could be made. In each case it was fixed so that the rays would pass to the canal at a right angle.

Regular, ultra-speed film was used in making the roentgenograms. Exposures were made at seventy-two inches, with seventy-five peak kilovolts, twenty milliamperes, for fifteen seconds.

In determining the location of the metaphysis it was noted that after closure of the epiphysis a suitable variation in density did not always appear to reveal the site of closure. Two specimens in the group revealed epiphyseal lines which were nearly obliterated. From these, points were found which were present in all of the specimens, and which showed definitely the plane where metaphysis and epiphysis fused.

It then became possible to measure the over-all length of the shaft and the distance between Digby's "site of initial ossification" and the distal and proximal ends of the shaft.

EXPERIMENTAL DATA

Group A

Forty-eight specimens were measured. The maximum length of diaphysis encountered was 45.5 centimeters (Specimen 103), and the minimum length was 34 centimeters (Specimen 94). The maximum growth from a distal epiphyseal line was 34.5 centimeters (Specimen 14), and the minimum growth from a similar structure was 18.5 centimeters (Specimen 24). The length of the shaft in the former (Specimen 14) was 43.5 centimeters, and in the latter (Specimen 24) 37 centimeters. As a result, the greatest individual growth from a distal epiphyseal line was 79 per cent., while the smallest percentage of growth was 50 per cent. (Table I). The remaining bones exhibited growth percentages which fell between these extremes.

After the percentage growth from the distal epiphyseal line in each femur had been established, a percentage growth mean for the series could be computed. This figure was 71 per cent. Yet it gave no indication of the variation from the mean. This latter figure is known as the Standard Deviation and is derived from the formula:

$$S\,D = \sqrt{\frac{\textit{Sum of the squares of the observations}}{\textit{Number of observations}} - (\textit{Mean of the observation})^2}$$

In this series the Standard Deviation from the mean was $\pm$ 6.5 per cent. Therefore, the average percentage of growth to be expected from the distal epiphyseal line in a femur would be in the range between 64.5 per cent. and 77.5 per cent.

Group B

This group was composed of six femora exhibiting dual arterial supply. The method was the same as that used in Group A except that a needle was inserted into each arterial canal before the plates were made.

A study of these films revealed that in four of the femora the expected intersection of the prolonged nutrient canals did not occur. Table II reveals the diaphyseal length in these bones and the distance from the distal metaphysis to each medullo-nutrient canal intersection.

In the remaining two femora the arteries intersected. The measurements obtained and the resulting proposed percentage of growth from the distal epiphyses are shown in Table III.

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Group B

This group was composed of six femora exhibiting dual arterial supply. The method was the same as that used in Group A except that a needle was inserted into each arterial canal before the plates were made.

A study of these films revealed that in four of the femora the expected intersection of the prolonged nutrient canals did not occur. Table II reveals the diaphyseal length in these bones and the distance from the distal metaphysis to each medullo-nutrient canal intersection.

In the remaining two femora the arteries intersected. The measurements obtained and the resulting proposed percentage of growth from the distal epiphyses are shown in Table III.

TABLE II

MEASUREMENTS IN WHICH ARTERIAL PROLONGATIONS DID NOT INTERSECT

Specimen Number	Diaphyseal Length (Centimeters)	Length from Distal Artery (Centimeters)	Length from Proximal Artery (Centimeters)
101	38.5	34	29
98	40.5	34.5	29.5
97	39	31	25
108	42.5	32	25.5

TABLE III

MEASUREMENTS IN FEMORA WHOSE ARTERIAL PROLONGATIONS INTERSECTED

Specimen Number	Diaphyseal Length (Centimeters)	Growth from Distal Epiphyseal Line (Centimeters)	(Per cent.)
107	38.5	28.5	75
99	43	31.5	73

Group C

Two new-born infant femora composed this group. One of these possessed a single nutrient artery. The other was found to have a dual arterial supply.

Measurement of the first revealed the distance from the metaphysis to the medullo-nutrient artery point to be 6.5 centimeters. In the second case the prolongation of the nutrient arterial canals did not intersect in the medullary cavity. As a result, measurements were deemed unnecessary.

DISCUSSION

From the most casual evaluation of the above data it would seem obvious that the original premise is without foundation. Two facts seem evident: first, considering the method of measurement as postulated by Digby to be sound, there is too much variation around the mean, in a large series of cases, to warrant the use of an estimated percentage of growth from a given epiphyseal line; second, the assumption that two nutrient arteries intersect in the medullary cavity at a point indicating the oldest part of the bone is false. This is clearly demonstrated by four of six adult femora which possessed dual arterial supply; and is further substantiated by the fact that at birth these arteries do not of necessity intersect. Because of this, it is felt that the method outlined for estimating percentage of growth from a given epiphyseal line is unsound and the figures are unreliable.

CONCLUSION

1. The established method, or Digby's method, of determining percentage of growth from a given epiphyseal line in a long bone (by comparing the diaphyseal length with the distance from the metaphysis to the intersection of the nutrient artery and the center of the medullary cavity) is unreliable and without foundation.
2. The figures derived by the use of this method in estimating the percentage of growth from a given epiphyseal line are inaccurate.

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ADHESIVE CAPSULITIS OF THE SHOULDER

A Study of the Pathological Findings in Periarthritis of the Shoulder *

BY JULIUS S. NEVIASER, M.D., WASHINGTON, D. C.

Periarthritis of the shoulder has long been familiar to orthopaedic surgeons. Other names applied to this condition are "frozen shoulder", "stiff and painful shoulder", "periarticular adhesions", "tendinitis of the short rotators", "adherent subacromial bursitis", "scapulohumeral periarthritis", and "Duplay's disease". The clinical picture is characterized by pain and limitation of motion in abduction, and in both internal and external rotation.

The consensus of opinion of most of the many writers on the subject may be summed up in a few pertinent statements. The condition is regarded as a separate clinical entity. Little is known of its pathology, and exposure of the bursa in a few instances has revealed no consistent abnormality. Motion was restored only after adhesions had been overcome. The adhesions were probably in the substance of the tendinocapsular structures.

This study was undertaken with the hope that through surgical exploration of the shoulder joint some light could be thrown on the pathology of this condition. In ten such cases, the operative findings were noted, and some were recorded in motion pictures as well. In addition, sixty-three shoulders of thirty-six persons who died from various causes were exposed at autopsy, and specimens were taken for microscopic study.

With one exception, upon roentgenographic examination, the patients selected for operation showed no changes in and about the shoulder joint. The exception (Case 7) revealed a calcification in the short rotator cuff. All patients had pain with limitation of motion in abduction and in both internal and external rotation. Forward flexion and backward extension were painless and not limited. After the operation on the first patient, oxygen was injected into both shoulder joints of the three subsequent cases, under local anaesthesia. This was done in an effort to determine whether or not oxygen would distend the capsule and show an air space around the head of the humerus in the normal shoulder. It was felt that an adherent capsule in the abnormal shoulder would prevent the entrance of much oxygen and thus would not reveal a distended capsule. (However, the tests were equivocal and without clinical value, and were subsequently omitted.) The affected shoulders of these three patients were then explored by operation as in the other seven cases.

At this point it might be well to review the anatomy of the normal shoulder joint. The articular capsule completely envelops the joint. It is remarkably loose, and this accounts for much of the free movement of this joint in all directions. The capsule is prolonged downward in the form of a fold in the ordinary dependent position of the arm (Fig. 1). When the arm is abducted, this fold becomes obliterated and the capsule tense. Synovial membrane lines the fibrous layer of the capsule. It extends from the margins of the glenoid cavity over the inner surface of the capsule, and covers the lower part and sides of the anatomical neck of the humerus, where it is reflected toward the margin of the articular cartilage of the humeral head. It is important to remember that the inferior aspect of the humeral neck has the most extensive clothing of synovial membrane (Figs. 1 and 2). On all aspects, except the inferior, the capsular ligament is supported by muscles, the tendons of which are more or less intimately connected with it. This intimate union of the tendons of the supraspinatus, infraspinatus, teres minor, and subscapularis muscles converts them into supporting ligaments of the joint. The entire enveloping structure is generally called the capsulotendinous or musculotendinous cuff of the shoulder.

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 26, 1944.

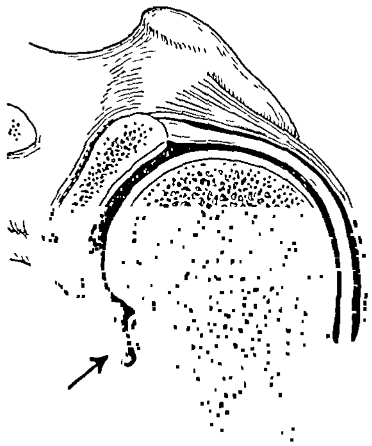

Fig. 1

A vertical section through the shoulder joint, showing (*A*) the fold of capsule of the joint with the synovial membrane lining its inner surface.

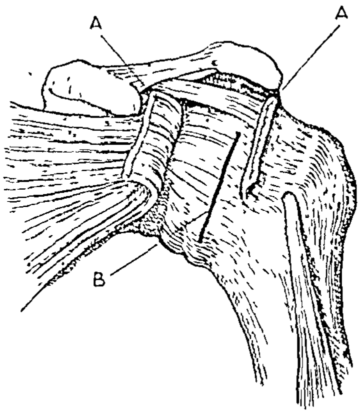

Fig. 2

Capsule of shoulder joint, exposed by section of (*A*) tendon of subscapularis. *B* indicates line of incision in the capsule.

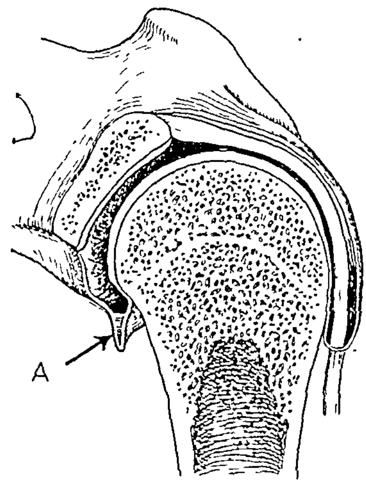

Fig. 3

A vertical section through the shoulder joint, showing the adhesion of (*A*) the reflected dependent part of the capsule.

However, in this paper, when reference is made to the term capsule, it signifies the true articular structure, particularly the synovial lining and subsynovial tissue.

The incision used for the exploratory arthrotomy was about ten centimeters long, following the line of separation between the deltoid and pectoralis major muscles. The cephalic vein was retracted in a lateral direction, and the muscle fibers were separated by blunt dissection. The subacromial bursa showed no gross pathological changes. The coracobrachialis and short head of the biceps were retracted strongly in a medial direction. The fibers of the subscapularis were separated from the capsule close to their insertion by means of a pointed elevator, and then divided by a vertical incision approximately 2.5 centimeters long. This gave a satisfactory exposure of the anterior portion of the capsule. This was divided by an oblique incision about 1.25 centimeters from the attachment of the capsule to the anatomical neck (Fig. 2). Its length varied somewhat in the series; the average was 3.75 centimeters.

An incision in the capsule, placed in this manner, normally opens into the joint with a consequent escape of synovial fluid. In all of the frozen shoulders, however, there was a conspicuous absence of synovial fluid and the redundant capsule, instead of showing the normal separation from the humeral head, was adherent to it. By means of a suitable elevator, the capsule could easily be separated from the cartilage. No bleeding could be detected during this procedure, thus indicating that the adhesion was not due to vascular bands. This adhesion was similar to that of adhesive plaster applied to the bare skin. The capsule could also be separated from the head by rotating the arm; in fact this was the method used in most of these cases. During manipulation, the head and the capsule, at first seemingly glued together, were separated after one or two rotational movements. Free rotation was then possible. It was evident that the capsule had been under tension, because the two cut edges retracted, leaving a gap of about two centimeters. The capsule was thicker than normal, as observed in cadaver experiments and in operations for recurrent dislocations. At the reflection of the capsule near the anatomical neck, a tearing apart of the adhesions binding the fold of the capsule was seen distinctly. During the abduction manoeuvre, it was possible to observe a space between the capsule and the humeral head.

In most instances, after manipulation, the margins of the divided capsule retracted so much that they could not be sutured together without a great deal of tension. Therefore, in closing, the capsular wound was never sutured. The patient was treated postopera-

tively in the same manner as if a closed manipulation had been done. It should be emphasized that this operative procedure is not offered as a treatment. It is merely described in detail to bring out the gross pathological findings. At operation, sections were taken from the bursa, capsule, and humeral head for microscopic study.

The shoulders of ten patients suffering from "frozen shoulder" or "periarthritis of the shoulder" were explored at operation. Cultures taken from these joints were negative. In nine cases, the capsule was contracted and closely adherent to the humeral head at its anterior inferior portion. Adhesions were discernible at the reflected fold of capsule distal to the anatomical neck (Fig. 3). In Case 8, the capsule did not snap free during the manipulation, as was true in the other nine cases, although initial inspection anteriorly revealed it to be tense. After manipulation, however, the capsule could be picked up loosely from the articular cartilage. The cause of this difference could not be visualized through our operative incision. In Case 10, a tenosynovitis of the long head of the biceps tendon was observed.

The sections of bursa and capsule taken from these shoulders revealed microscopic changes in either or both. Removal of sections of articular cartilage was discontinued, after four had shown a picture consistent with the usual degenerative changes from wear and tear.

CASE STUDIES

CASE 1. P. F., colored female, fifty-six years old, came to the orthopaedic clinic at The Emergency Hospital complaining of pain in the left shoulder of two months' duration. There was no history of injury. Pain was severe when attempts were made to use or to exercise the left arm, and became worse at night. Roentgenograms were negative. Shoulder motion was restricted in abduction, and in internal and external rotation. An arthrotomy of the left shoulder was performed on February 8, 1940. At operation, the capsule appeared to be hypertrophied and contracted over the head of the humerus. During manipulation of the arm, the capsule gradually became separated from the humeral head.

Microscopic Findings:

Bursa: Beginning hyalinization of the synovial villi was apparent. There was also fibrosis and cellular infiltration by mononuclear leukocytes of the bursal wall. There was vascular dilatation of the blood vessels.

Capsule: Synovial cells revealed no change. There was a fairly extensive fibrosis and chronic inflammation of the subsynovia manifested by infiltration of mononuclear leukocytes. Some perivascular infiltration was noted.

CASE 2. I. D., white male, sixty-three years old, came to the orthopaedic clinic at The George Washington University Hospital, complaining of pain in the left shoulder of about three months' duration. Pain had gradually increased, until the patient could not raise his arm or place his left hand behind him. The only history of injury was a fractured left arm suffered at the age of two years. Roentgenograms were negative. All motions were restricted, except forward and backward flexion. Oxygen injection, as described before, gave no information. An arthrotomy of the left shoulder was performed on April 26, 1941. The capsule, which was contracted and firmly adherent to the anterior inferior portion of the humeral head, peeled away when the arm was manipulated.

Microscopic Findings:

Bursa: Vascular dilatation with a slight degree of fibrosis of the synovial lining was noted. The hyalinization of some of the villous folds (Fig. 4) suggested the possibility of a pre-existing bursitis.

Capsule: The synovial cells were normal. There was vascular dilatation in the subsynovia.

Cartilage: Normal.

CASE 3. S. P., white male, fifty-six years old, was seen in the orthopaedic clinic at The Emergency Hospital, complaining of pain in the right shoulder of three months' duration. He described the pain as a dull ache, especially upon movement of the arm. Thirty-six years before, he had broken his right forearm, but had had no trouble from this injury. Roentgenograms were negative. There was definite limitation of motion in abduction and in external rotation, and internal rotation was also restricted. Oxygen injection was of no value. At operation on April 28, 1941, a thickened and adherent capsule was found. Upon manipulation, the capsule snapped off the humeral head, allowing complete freedom of motion. This case illustrated the contracture of the capsule and the adhesions so well that the decision was made to take motion pictures of subsequent cases.

FIG. 4

Case 2. Photomicrograph (×100) shows (*a*) hyalinization of some of the villous folds and (*b*) vascular dilatation of the bursa.

Microscopic Findings:

Bursa: The bursa was inflamed. Attached directly to the synovial surface was a veil-like mass of fibrin in the meshes of which were moderate numbers of mononuclear leukocytes (Fig. 5-A). There was proliferation of the synovial cells. Perivascular round-cell infiltration of the blood vessels was noted. It was decided that chronic bursitis was probably responsible for the patient's condition.

Capsule: Here too was a definite inflammatory response. There was a moderate degree of perivascular infiltration with lymphocytes. Cystic degeneration or oedema was noted in the subsynovia (Fig. 5-B). There was no synovial lining in the section.

Cartilage: Cystic degeneration.

CASE 4. M. O., white female, fifty-eight years old, was seen at the orthopaedic clinic of The George Washington University Hospital, complaining of pain in the right shoulder. Eight months previously she had had a severe infection in the index finger of the right hand, which had cleared up after several weeks of treatment. The patient was a diabetic. Four months later she had begun to have pain on motion in the right shoulder, which became progressively worse. Three weeks before examination, the pain had become quite severe, and she had started to have definite limitation of motion. Roentgenograms were negative. Oxygen injection was valueless. Motions were definitely limited in abduction, and in external and internal rotation. An arthrotomy was performed on June 30, 1941. A thickened and adherent capsule was found. During the manipulation, the capsule peeled away from the humeral head. Motion pictures were made of this case.

Microscopic Findings:

Bursa: Showed a slight increase in the blood vessels in the synovia.

Capsule: There was no synovial lining in the section. There was a moderate fibrosis of the subsynovia, a slight degeneration of the collagen, and a focal area of calcification (Fig. 6).

Cartilage: There was considerable fibrillation of the hyaline cartilage indicating degeneration.

FIG. 5-A

Case 3. Photomicrograph (×100) shows (*a*) proliferation of the synovial cells of the bursa. Attached directly to the synovial surface (*b*) there is a veil-like mass of fibrin in the meshes of which are moderate numbers of (*c*) mononuclear leukocytes.

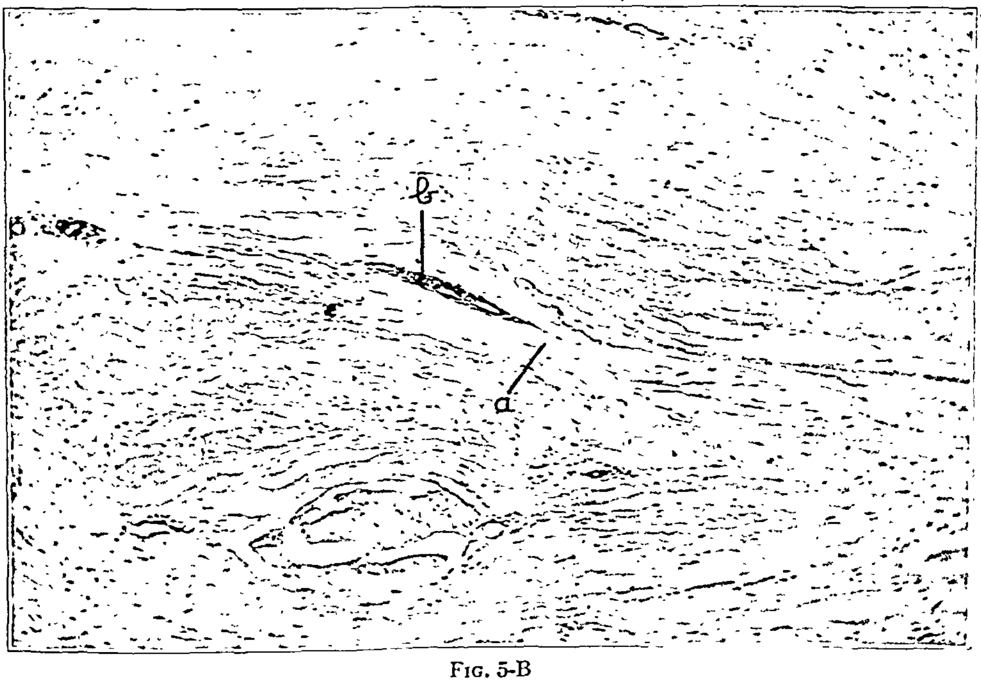

FIG. 5-B

Case 3. Photomicrograph (×80) shows (*a*) oedema in the subsynovia of the capsule and (*b*) perivascular cuffing.

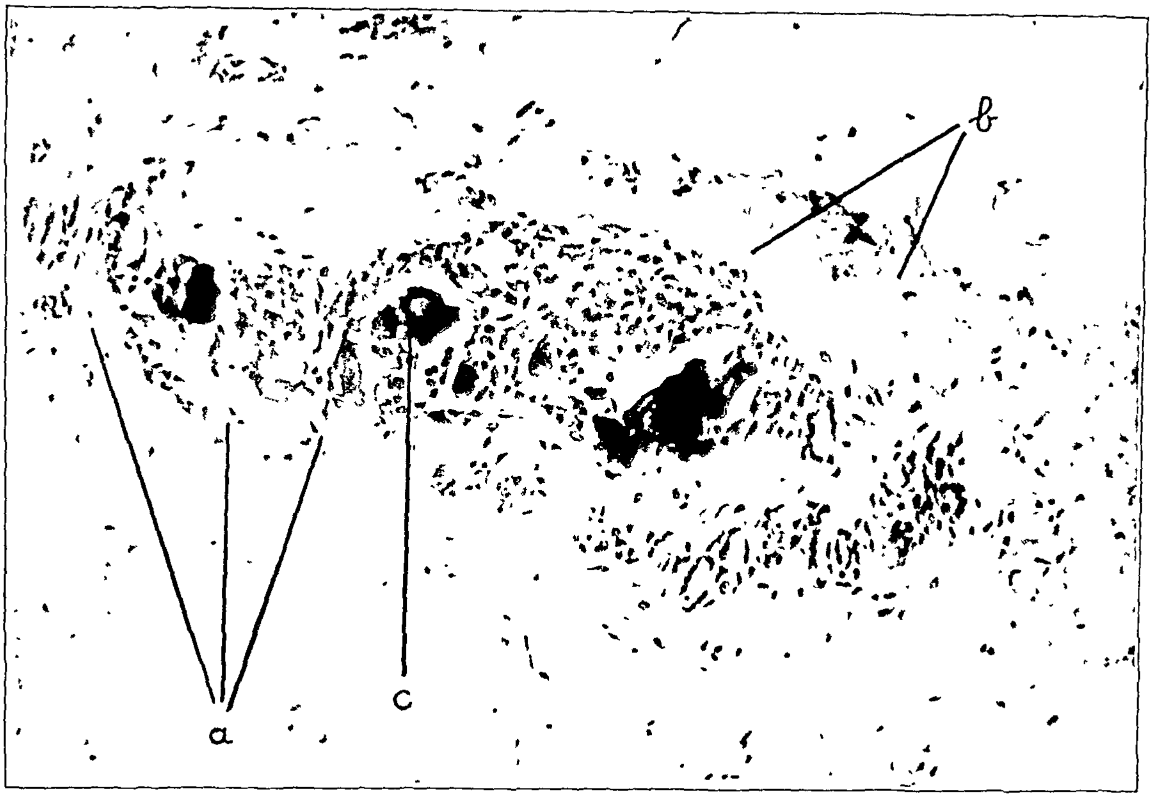

FIG. 6

Case 4. Photomicrograph (×80) of capsule showing (a) fibrosis of subsynovia, (b) slight degeneration of collagen, and (c) a focal area of calcification.

CASE 5. L. L., white male, sixty-one years old, seen at the orthopaedic clinic of The George Washington University Hospital, complained of pain in the left shoulder of six months' duration. Onset of pain in both shoulders was gradual, but after two weeks, pain disappeared in the right shoulder and persisted in the left shoulder. Pain had been worse during the last two weeks. Roentgenograms revealed no changes in the shoulder joint. Although abduction and external rotation were limited, internal rotation was particularly restricted. Operation was performed on May 7, 1942. During the manipulation, the capsule quickly separated away from the head of the humerus with a tearing apart of the synovial folds. Findings were recorded by kodachromes.

Microscopic Findings:

Bursa: There was slight proliferation of synovial cells, and fibrosis and chronic inflammation in the subsynovia.

Capsule: There was a slight proliferation of the lining synovial cells of the capsule, as well as a few scattered cells, mostly lymphocytes, about the vessels in the subsynovia.

Cartilage: There was a slight degree of degeneration of the hyaline cartilage.

CASE 6. M. S., white female, forty-six years old, complained of pain in the left shoulder and inability to use her left arm freely. Pain had been present for five months, and had become so severe that the patient had to walk the floor at night. She had undergone chiropractic treatments without relief. There was the usual restriction of motion, with abduction of 45 degrees, and she was unable to touch the left buttock with her left hand. Roentgenograms were negative. Motion pictures were taken of the operation on June 15, 1942. The thickened contracted capsule quickly peeled off the articular cartilage during the manipulation.

Microscopic Findings:

Bursa: There were a few lymphocytes in the wall of the bursa, and a slight proliferation of the synovial cells.

Capsule: The synovial capsule was essentially normal.

CASE 7. D. D., white female, thirty-three years old, complained of pain in the right shoulder of five years' duration. She had been told that she had a calcified subdeltoid bursa. She had had episodes of pain during that time, and had been treated by diathermy, x-ray, and aspiration with temporary relief. She was seen by Commander Robert Mazet on May 5, 1942, who noted pain but a good range of motion. Roentgenograms taken on May 8 revealed a large calcified bursa in the right shoulder. When seen again on July 6, she had extreme pain and practically no range of motion except forward and backward flexion. The operation

was performed on July 10, 1942, by Captain Hook and Commander Mazet (this case was presented through their courtesy). After the subdeltoid bursa had been exposed and the calcified material allowed to escape, the shoulder still remained restricted in motion. After the incised adherent capsule had been manipulated, it suddenly snapped away from the head of the humerus, allowing it to become free, with full range of motion in the shoulder.

Microscopic Findings:

Bursa: There was a moderate amount of fibrosis and chronic inflammation of the bursal wall, characterized by the presence of mononuclear leukocytes.

Capsule: There was one small area of calcification in the subsynovia. There was no synovial lining in the section.

Case 8. F. K., white male, fifty-two years old, examined for pain in the left shoulder of six months' duration. He attributed the trouble to "exposure to draft". Pain had been worse in the last month, and he could not use the arm freely. There was no history of injury. He had not received treatment. Active abduction was limited to 60 degrees. Internal and external rotation were also limited. Roentgenograms revealed no changes in the left shoulder. The shoulder was exposed on August 24, 1942. In this instance, the adherent capsule did not snap free or peel off the humeral head during the manipulation, but after this procedure it became loose and could be easily raised from the articular cartilage by a forceps. It is believed that the adhesions in this case were probably so situated that it was impossible for the surgeon to visualize them.

Microscopic Findings:

Bursa: The bursa showed no alteration of importance.

Capsule: There was no synovial lining in the section. There was considerable fibrosis and degeneration of the collagen of the subsynovia (Fig. 7).

Case 9. D. C., white female, was forty-seven years old. Three months before the examination, the patient had had trouble with her left arm, with a gradual onset of slight pain in the shoulder, which became quite severe at night. Active abduction was limited to 70 degrees. External rotation was more restricted than internal rotation. Roentgenograms revealed no evidence of any bone or joint changes in the left shoulder. An arthrotomy was performed on the left shoulder on October 19, 1942. During manipulation of the shoulder, the contracted capsule peeled off the head of the humerus, allowing the arm complete range of motion.

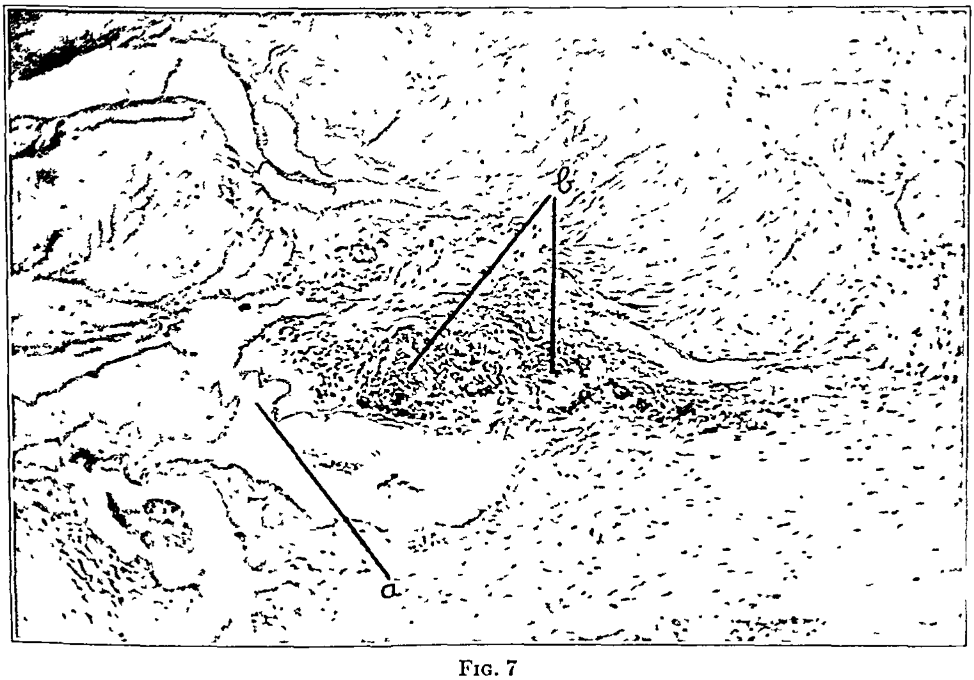

Fig. 7

Case 8. Photomicrograph (×80) of capsule shows (*a*) degeneration of collagen of the subsynovia and (*b*) vascular dilatation and perivascular infiltration.

Microscopic Findings:

Bursa: There was no evident change in the bursa.

Capsule: There was moderate fibrosis and considerable perivascular lymphocytic infiltration (Figs. 8-A and 8-B).

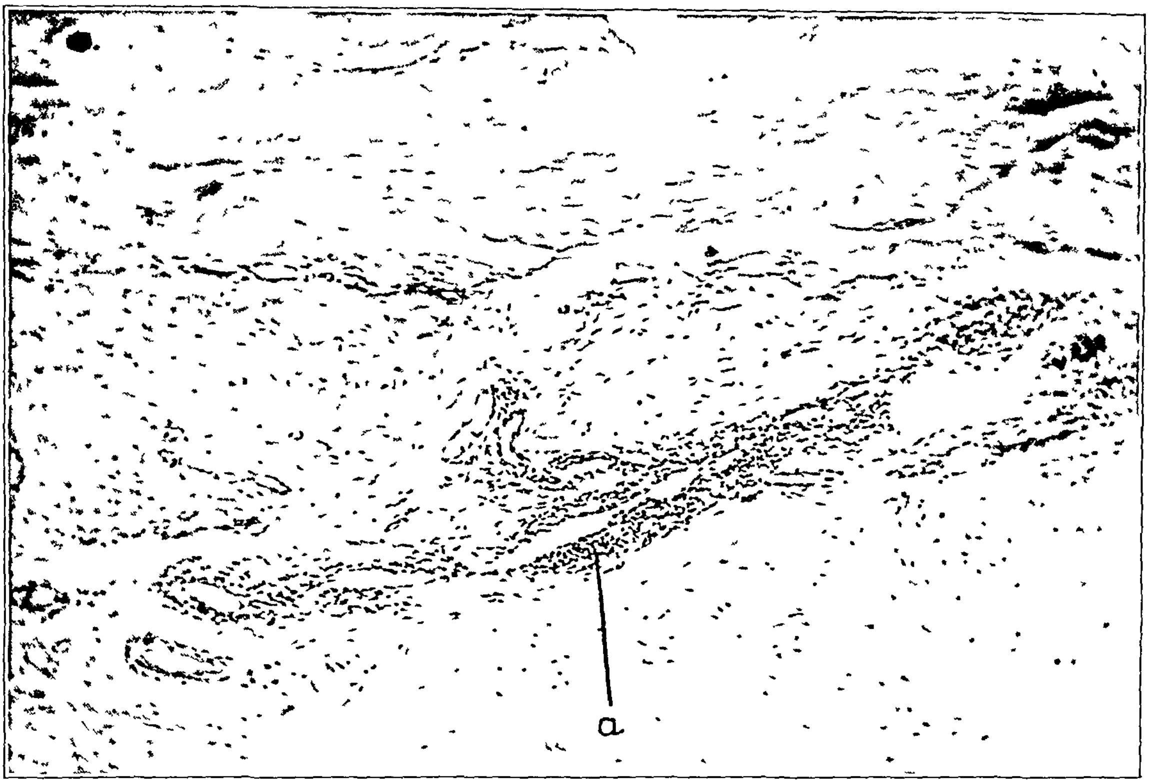

FIG. 8-A

Case 9 Photomicrograph (×80) shows (*a*) perivascular lymphocytic infiltration in the capsule.

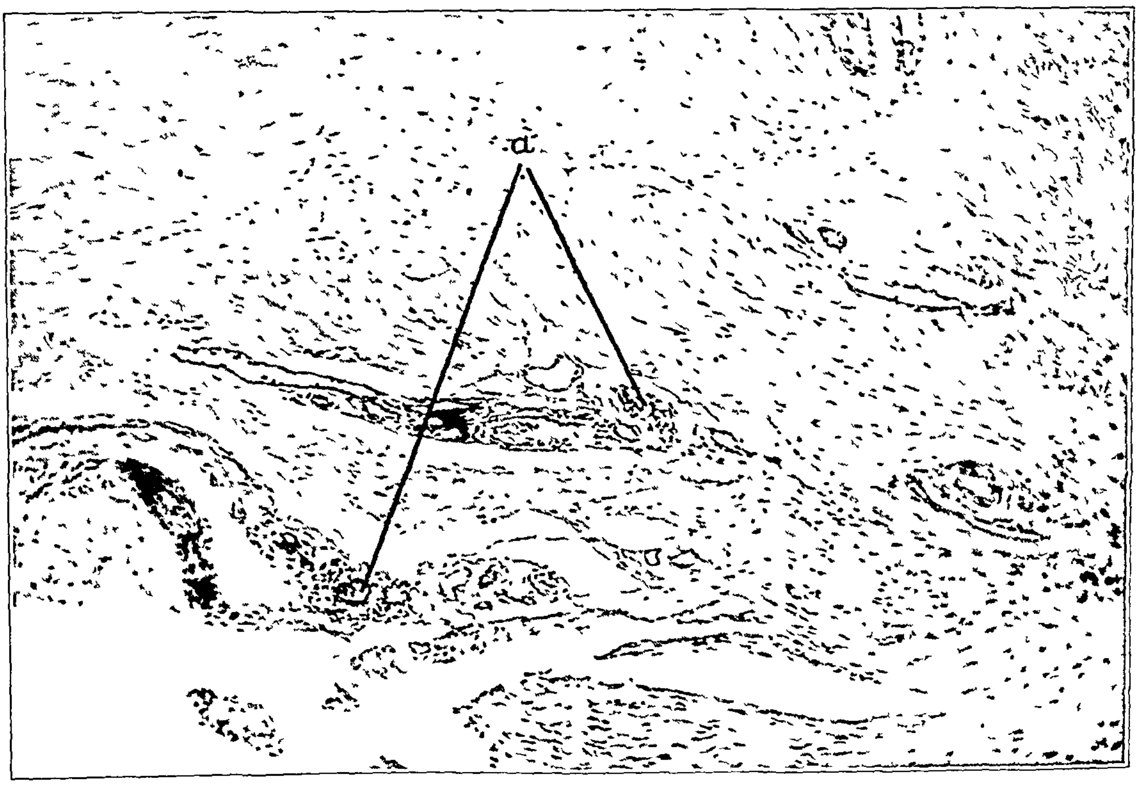

FIG. 8-B

Case 9. Photomicrograph (×80) of another section of capsule showing (*a*) perivascular lymphocytic infiltration.

Case 10. D. L., white male, forty-five years old, had fallen from a ladder injuring his left shoulder seven weeks before admission. Roentgenograms were negative. He had been treated by diathermy and ordered to rest. His arm was in a sling for about two weeks. With active motion, the arm pained him so that it kept him awake at night. Active abduction was 90 degrees. External rotation was limited to about 30 degrees. Internal rotation was restricted so that the left hand touched back just above the belt line. Forward flexion and backward extension were good. Operation was performed on the left shoulder on August 9, 1943. A tenosynovitis of the long head of the biceps tendon was observed. The incision showed the capsule so contracted and tightly adherent to the humeral head that it was difficult to insert a flat instrument between it and the head of the humerus. After manipulation, when the capsule snapped free and the synovial folds tore apart, this was easily accomplished.

Microscopic Findings:

Bursa: No abnormal changes were noted.

Capsule: Chronic inflammatory changes were manifested by infiltration of mononuclear leukocytes, and the presence of granulation tissue. There was absence of synovial cells.

SUMMARY

Bursa: There were varying degrees of inflammation of the bursa in seven of the ten cases examined.

Capsule: The synovial lining in the ten cases examined (Table 1) did not present a continuous layer of cells in all sections. In four instances the cells which were present

TABLE I

Pathological Description of Tissues Taken from Patients with "Frozen Shoulders"

Synovia (Capsule)			Bursa			Cartilage
Synovial Cells	Subsynovia	Blood Vessels	Synovia	Subsynovia	Blood Vessels	
Negative	Fibrosis and chronic inflammation	Perivascular infiltration	Beginning hyalinization of villi	Fibrosis and chronic inflammation	Vascular dilatation	
Negative	Vascular dilatation	Altered to simulate granulation tissue	Fibrinoid necrosis	Negative	Increase in thin-walled blood vessels.	Negative
——	Cystic degeneration	Perivascular infiltration	Proliferation and fibrin	Extensive inflammation	Perivascular round-cell infiltration	Cystic degeneration
——	Calcification. Fibrosis. Degeneration of collagen	Slight perivascular infiltration	Slight increase in blood vessels	Negative	Negative	Fibrillation
Slight proliferation	Negative	Perivascular infiltration	Slight proliferation	Fibrosis and chronic inflammation	Negative	Slight degeneration
Negative	Negative	Negative	Slight proliferation	A few lymphocytes	Negative	
——	Calcification	Negative	Negative	Fibrosis and chronic inflammation	Negative	
——	Fibrosis and degeneration of collagen	Dilatation and perivascular infiltration	Negative	Negative	Negative	
Negative	Fibrosis	Perivascular infiltration	Negative	Negative	Negative	
——	Chronic inflammation	Altered to form granulation tissue	Negative	Negative	Negative	

[No]te: —— indicates absence of synovial cells.

TABLE II

Analysis of Autopsy Cases Which Revealed Adherent Capsules

Case and Number	
C. K. 57789	Both shoulder capsules were contracted when removed. They were firmly adherent to the articular cartilage. The reflected folds were adherent. Microscopic changes consisting of fibrinoid necrosis and lymphocytic infiltration were seen only in left capsule.
C. M. 57800	Nothing was found either on gross or microscopic examination of right shoulder capsule. In left shoulder a large adhesive band was found anteriorly close to the anatomical neck Fibrosis was noted in subsynovial layer.
C. B. ——	Right shoulder capsule was adherent. Slight proliferation of synovial cells and fibrosis was noted in subsynovial layer.
C. E. 57829	Both capsules were contracted and adherent to the humeral head. Proliferation of synovial cells was noted.
L. P. 57835	Capsules were quite adherent throughout in both shoulders. Reflected folds were slightly adherent. No microscopic changes were noted in right capsule, but inflammation was observed in left capsule.
C. S. 57671	Both capsules were contracted and firmly adherent over articular cartilage and difficult to remove. Patient had chronic arthritis but gave no history of shoulder pains. No gross arthritic changes were noted in the shoulder joint. Fibrosis and degeneration of collagen were noted in both capsules.

appeared normal; in one instance they showed evidences of proliferation; and in the five remaining cases no synovial cells were found. In these five cases it is probable that the synovial cells, which were originally present, had been destroyed in the formative stages of the process or during manipulation at the time of operation.

In the subsynovial layer there was fibrosis and degeneration of the collagen in two instances, calcification in two, and chronic inflammation characterized by fibrosis and perivascular infiltration in six instances.

The blood vessels were essentially normal.

Elastic-tissue stains were also made of all sections, but they did not reveal any significant change in the collagen.

Hyaline Cartilage: There was a moderate amount of degeneration in three or four cases examined. These changes might well be within normal limits.

In all ten cases there were changes demonstrated in either the capsule or the bursa or both. The microscopic sections revealed a nearly consistent pathological picture of reparative inflammatory changes, which consisted of degeneration, vascular repair, cuffing of the blood vessels, and mononuclear cells to a lesser or greater degree.

DISCUSSION OF THE AUTOPSY CASES

The synovial capsules from both shoulder joints of twenty-seven patients who had died from various causes, and one shoulder from nine additional patients, were examined, making a total of sixty-three shoulders. The youngest were stillbirths and the eldest was eighty-seven years of age, the average age being forty-four and six-tenths years. There were no demonstrable differences between the right and the left side. Elastic-tissue stains were of no value.

There was fibrosis of the subsynovia, calcification, focal degeneration of the collagen, or a slight amount of chronic inflammation in fourteen of sixty-three shoulders (22.2 per cent.). It is of interest to note (Table II) that in eight of the fourteen shoulders which showed microscopic changes, the capsule was contracted and closely adherent to the humeral head. This would leave only six shoulders (9.5 per cent.) which showed microscopic changes in the capsule, but revealed no gross changes.

One of the six remaining shoulders (J. M., No. 57391) showed an acute inflammatory process, characterized by an infiltration of polymorphonuclear leukocytes in addition to a more diffuse chronic process, consisting of an infiltration of small mononuclear leukocytes distributed chiefly around blood vessels. This acute inflammatory reaction is not part of the pathological entity which forms the basis of this paper. Interestingly enough, the capsule was not contracted or adherent at the time of its removal.

CONCLUSIONS

This study of "frozen shoulder" was undertaken to clarify the pathology, and is not offered as a method of treatment. The results demonstrate that the lesion is not a periarthritis, but the essential pathology is a thickening and contraction of the capsule which becomes adherent to the humeral head. Microscopic sections confirm the presence of reparative inflammatory changes in the capsule. In some cases, there are also similar changes in the wall of the subacromial bursa. During manipulation of a "frozen shoulder" under anaesthesia, the capsule is separated from the head in much the same way that adhesive plaster can be torn away from the bare skin. Once this separation has occurred, motion of the head within the joint is free.

The term "adhesive capsulitis" is suggested as descriptive of the pathology of "frozen shoulder".

NOTE: The author is greatly indebted to Colonel J. E. Ash, Lieutenant Colonel D. Murray Angevine, and Major Alfred Golden of the Army Medical Museum for their kind cooperation, their complete review of the pathological material, and their many helpful suggestions.

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RESULTS OF MODERN METHODS OF TREATMENT OF POLIOMYELITIS *

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A reappraisal and a report of our successful, although unspectacular, treatment of poliomyelitis patients at the Children's Hospital School, and elsewhere in Baltimore, may prove helpful and enlightening to orthopaedic surgeons in other sections. The accurate and consistent records which we are fortunate in having make such a report possible. At the 1942 meeting of the Association in Baltimore, Dr. Raymond Lenhard [1] presented in considerable detail the complete figures on the cases treated between 1932 and 1938. The figures presented herewith include only the cases from the 1941 epidemic.

Our figures are presented for exactly what I think they are worth—interesting information—and I wish to state frankly that while I think our results are encouraging and satisfactory, they cannot be regarded as a primary justification of our regimen. I have confidence in our treatment because it is based on the sound foundation of the accredited pathology of the disease, and a reasonable conception of the pathological physiology of denervated muscle, its maintenance while paralyzed or weakened, the bone and joint physiology secondary to paralysis, and circulatory and nutritional factors.

In treating our patients, we try always to keep in mind the important general objective as well as the local one. We try to treat the individual person, not just an isolated extremity. For that reason the much advertized problem of "alienation" has never been a serious one for us. The training of the patient as well as his muscles are of almost equal importance. Briefly, our methods are as follows:

In the Acute Stage

1. Bed rest in a darkened room with complete quiet is important. Sedation is indicated for general restlessness or for pain.
2. Encouragement and reassurance are essential, not only for the patients themselves, but also for their families.
3. Protection in the form of half-shell plaster molds or "Toronto"-type splints should be provided for paralyzed, weakened, or tender extremities in positions of relaxation. In this way, physiological rest is assured for the affected muscles.
4. Frequent checks are made of muscle power within reasonable limits, to determine progress of the disease in the early days, and the results are charted. Hyperaesthesia or muscle tenderness is also checked and noted. Except in the encephalitic type, we have not had clinical evidence of spasticity in the paralyzed extremities. Stiff necks and backs are usual in the early days, but they tend to disappear spontaneously.
5. Radiant heat is administered intermittently as a painless stimulant to local circulation.

In the Convalescent Period

6. Gentle massage is administered to the paralyzed or weakened groups, and is increased slowly in depth and force as soon as hypersensitivity permits.
7. Passive motion within a limited arc is begun in joints where muscle power is below 50 per cent., and active motion is started in an increasing range, as the muscles grow in strength.
8. Graduated exercises are given for weakened muscles, in proportion to their ability, after a careful check has been made of their power. This requires skilled physio-

* Read at the Annual Meeting of The American Orthopaedic Association, Hot Springs, Virginia, June 1, 1944.

TABLE I

RESULTS OBTAINED—1941 SERIES

Number and Percentage of Muscles Attaining Final Grade of 80 Per cent. or More

First Examination Grade *	Total Number of Muscles Graded	Number Attaining Grade of 80 Per cent.	90 Per cent.	100 Per cent.	Total Attaining 80 Per cent. or More Number	Per cent.
0	64	0	0	0	0	0
5	34	2	0	1	3	9
10	34	2	0	5	7	21
20	29	8	4	5	17	59
30	50	3	3	23	29	58
40	52	4	4	33	41	79
50	29	0	8	19	27	93
60	74	3	5	63	71	96
70	50	0	4	45	49	98
80	40	0	0	39	39	98
Totals	456	22	28	233	283	62

* Based on Key to Muscle Grading (Table I)[1]. Briefly, the grades show the degree of restoration of function in paralyzed muscle groups, as achieved during interval examinations referred to in the text. The lowest grade or zero is given to muscles with no contraction, and intermediate grades up to 80 are given as function increases.

therapists with knowledge of physiological anatomy, and a quick sense of appreciation of the fatigue which comes so suddenly in partially recovered muscles. We are fortunate at the Children's Hospital School, for our staff is directed and has been trained by Mr. H. O. Kendall. He has an uncanny appreciation of muscle power and muscle fatigue, and a wonderful ability to impart his skill to others.

9. Education of the patients begins at once by getting their help in our program of protection and development. Those who seem destined to have some inescapable dis-

TABLE II

COMPARISON BETWEEN EARLIER SERIES AND 1941 GROUP

First Examination Grade	Percentage Attaining 80 Per cent. or Better 1932–1939 (Per cent.)	1941 (Per cent.)	Late Group 1932–1938 (Per cent.)
0	4	0	2
5	(Not included)	9	0
10	42	21	0
20	50	59	5.5
30	82	58	16
40	80	79	22
50	86	93	30
60	90	96	14
70	96	98	52
80	100	98	84
Percentages based on total of	701 muscles	456 muscles	103 muscles
Average over-all improvement to 80 per cent. or better	56.6 per cent.	62 per cent.	15 per cent.

TABLE III

Comparison of Results in the Three Groups of Patients

Group	Number of Muscles Tested	Muscles with 20 Per cent. or More Recovery	
		Number	*Per cent.*
Group I, Lenhard (Early and adequate treatment)	701	578	82.4
Group II, Lenhard (Adequate treatment started five months to eighteen years after onset)	315	103	32.7
1941 Group (Early and adequate treatment)	456	358	78.7

ability are turned from invalidism and self-pity toward a healthy attitude of adaptability and compensation. In the wards, the children help one another to achieve this end, and are helpfully guided by staff members. It is an interesting fact that ward patients do much better in this respect than those patients in private rooms. Even the most seriously paralyzed patients improve in a more or less normal atmosphere until basic psychological adjustments can be attained.

10. Later we use underwater exercise in pools, but it is a difficult medium to use in early cases, as control of patient and affected part is less accurate, and, therefore, the danger of overfatigue is greater.

11. Our records are kept faithfully and accurately by Mr. and Mrs. Kendall, and the factor of error is less than 5 per cent. on repeated tests. It is on the basis of these charts of checks, made at least monthly during the first three months, and at least every three months during the first year, and twice a year thereafter, that our figures and conclusions are based.

One positive benefit from a crusade of the Sister Kenny type is that it makes us re-examine our own therapeutic procedures to find out if time, fashion, or carelessness have led us astray in any particular. So far we have remained unimpressed by the claims of superiority of the Sister Kenny treatment.

Certain fundamental facts about poliomyelitis should be stressed:

1. Patients are not cured; they recover, and we assist in the recovery.
2. It is more important for a badly paralyzed patient to recover to 80 or 90 per cent. of normal, than for a slightly weakened patient to make a complete recovery. Therefore,

TABLE IV

Muscles Recovering Up to 30 Per cent. After a Convalescence Period of Three Months, and 60 Per cent. or Better After Twelve Months

First Examination Grade	Number of Muscles	Number Attaining 60 Per cent. or Better	Percentage of Functional Recovery
0	17	0	0
5	16	5	31.3
10	17	7	41.2
20	20	15	75
Total	70	27	38.6

our figures are not rated in case units, for in this way misleading statistics may be produce

3. The proper unit is the weakened or paralyzed muscle itself, and recovery judged on final muscle power as compared with the original degree of paralysis. Eac muscle's record in each case is kept separately, and analyses and comparisons can be mad with these definite units without the introduction of variables. In this way, can be de termined the overall percentage of recovery, the recovery of the upper as compared to th lower extremity, the recovery of trunk and abdominal muscles, the rate of recovery, th effect of use, exercise, and other factors on recovery, and the prognosis for individua muscle recovery.

Inasmuch as these records provide us with almost astronomical figures, as they in volve more than 100,000 checks on muscles, we have selected for this analysis ten com monly paralyzed and very important muscles: gluteus maximus, gluteus medius, quadri ceps, hamstrings, gastrocnemius, tibialis anterior, deltoid, biceps humeri, triceps brachii and opponens pollicis.

The figures shown in Tables I, II, III, and IV represent an epidemic in which th cases were conservatively treated, as outlined above, and include sixty-four patients o both sexes and various ages. The paralyzed muscle units reported total 456, 350 in th lower extremity, and 106 in the upper extremity.

The author's work has been chiefly an elaboration and confirmation of Dr. Lenhard's In our analyses, a period of ten years has been covered, so it may be considered fairly representative of poliomyelitis in our section of the country.

CONCLUSIONS

1. All muscles, even in a widespread, complete paralysis of entire extremities should have three months of careful and painstaking protection and treatment comparabl to that given in peripheral-nerve lesions.

2. At the end of such a three months' regimen, a very accurate prognosis of recovery can be arrived at, for the muscles can then be differentiated into three categories:

a. Those which have not recovered to a point of 30 per cent. of power in thre months. No return of useful power is to be expected; and these make up the group of the permanently paralyzed extremities.

b. Those which by this time have 80 per cent. or more power, and can be counted on to function satisfactorily without any further treatment except general supervision.

c. The group which has demonstrated some return of power and has a three-month level of 30 to 75 per cent. These have potentiality for further recovery to a point where useful function can be restored. These cases are the crucially important ones as far as further active treatment is concerned, and every effort should continue to be expended on this group to build up power and develop hypertrophy of the active muscle tissue persisting, and to protect these patients against overfatigue and postural strain during at least the next year.

3. No appreciable recovery continues beyond eighteen months, even under ideal conditions, but untreated or inadequately treated cases have been salvaged by this regimen as late as six to ten years after the acute attack, indicating a previous nerve recovery which had been masked or nullified by the overstretching or overfatigue of the muscle or by opposing contracture.

4. On occasions we have observed loss of power in muscles of our own cases from overfatigue and too early removal of support, with permanent damage in some few instances, again demonstrating the need for careful supervision during recovery.

1. Lenhard, R. E.: The Results of Poliomyelitis in Baltimore. J. Bone and Joint Surg., XXV, 132, Jan. 1943.

BULLET FRACTURES OF THE LONG BONES

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Bullet fractures of the long bones require more careful treatment than any other serious fracture. The purpose of this article is to emphasize the importance of conservatism in the débridement and management of such fractures.

The term "bullet fracture" is used to denote a compound shattering of a long bone (Figs. 6-A, 6-B). While any sudden severe injury may result in a fracture of this type (Figs. 3-A, 3-B), a bullet or a fragment of metal casing from an explosive missile is the usual cause. The fracture resulting from a direct hit by a high-velocity bullet is typical, and is characterized by multiple small fragments of bone in a compound wound.

The Office of the Surgeon General has outlined the principles of wound treatment in Circular Letter Number 178, dated October 23, 1943:

"1. Adequate exposure in order to permit access to all parts of the wound. . . . Very little skin need be excised, but good exposure may necessitate longitudinal incision of the skin and the fascia planes.

2. Removal of:

   a. Readily accessible foreign bodies. . . .

   b. Particles of bone completely separated from the periosteum.

   c. Tissue that is soiled, devitalized, or the circulation of which is impaired. . . .

3. Leave wound open.

4. Dressing should be placed loosely in the wound, not packed.

5. In large wounds, immobilize the part by adequate splinting, even in the absence of fractures."

Three of these principles are of particular importance: (1) removal of only those bony fragments which are completely separated from the periosteum; (2) placing of dressings loosely in the wound; (3) complete and prolonged immobilization.

The utmost caution should be observed in the débridement of bullet-fracture wounds. Loose and completely detached particles of bone should be removed, but bony fragments with periosteal and soft-tissue attachment should be left undisturbed, so that they may act as struts or live bone grafts for the restoration of the shaft of the bone. The result is a tremendous saving in time and function, and often of the limb itself. Fragments at-

FIG. 1

Bullet fracture of femur caused by forty-five caliber revolver bullet. Roentgenogram taken after six weeks, when manipulation was attempted to correct posterior bowing. Fracture was so solid correction was not obtained. There was no deep drainage from the two granulating wounds.

FIG. 2-A

Bullet fracture of femur caused when soldier's motorcycle collided head on with truck during a blackout.

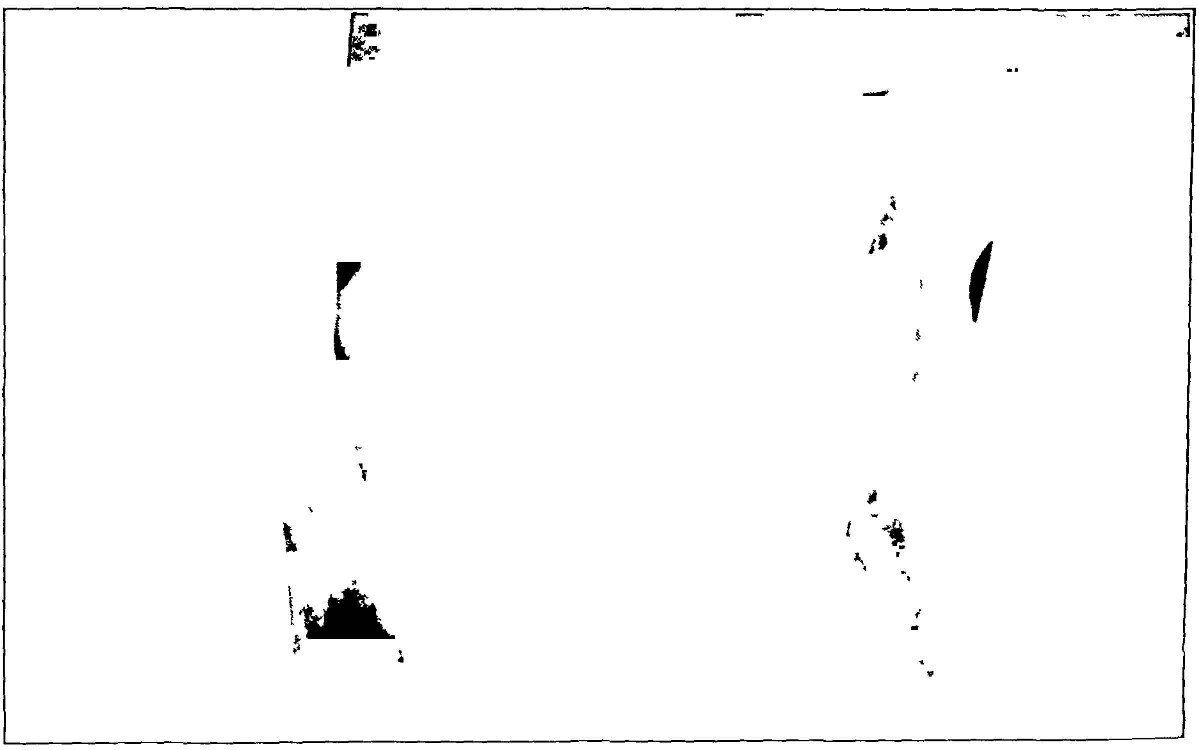

FIG. 2-B

Shows solid healing of fractured femur after ten months. Patient has been walking in a caliper brace for one month. Anterior bone fragment projected into the quadriceps, and has been removed to facilitate quadriceps and knee motion.

tached to the periosteum rapidly set up a barrier to infection, whereas removal of the fragments, instead of preventing or arresting deep infection, creates a dead space in which

FIG. 3-A

FIG. 3-B

Fig. 3-A: Fresh bullet fracture of humerus caused by Japanese rifle bullet.

Fig. 3-B: Shows degree of healing six months after injury, two small sinuses, one anterior and one posterior, persist. A small sequestrum is present in dead space of bone.

FIG 4

Roentgenogram taken six weeks after humerus was shattered by German machine-gun bullet. Degree of healing was very fast Wounds have healed except for dime-sized pouts of granulation tissue at points of entrance and exit of bullet Hanging cast was removed at this stage.

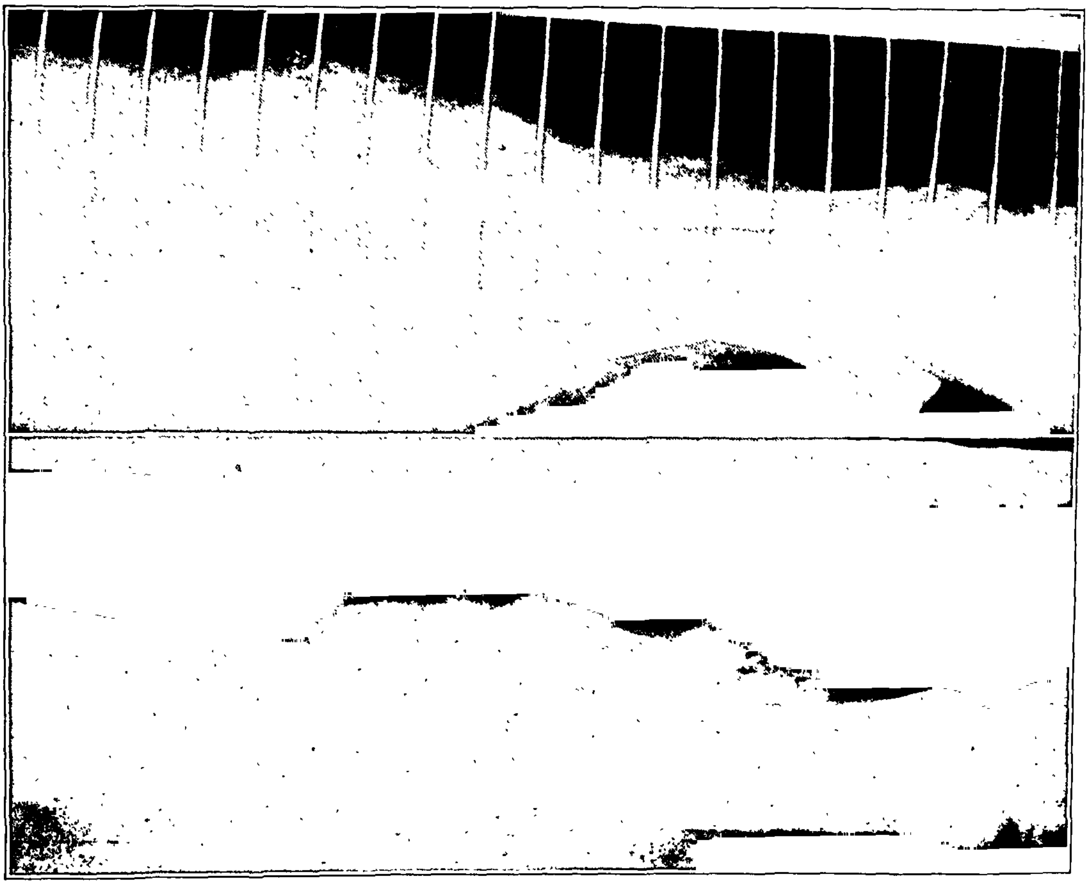

Fig. 5-A

Bullet fracture of tibia caused by enemy rifle bullet.

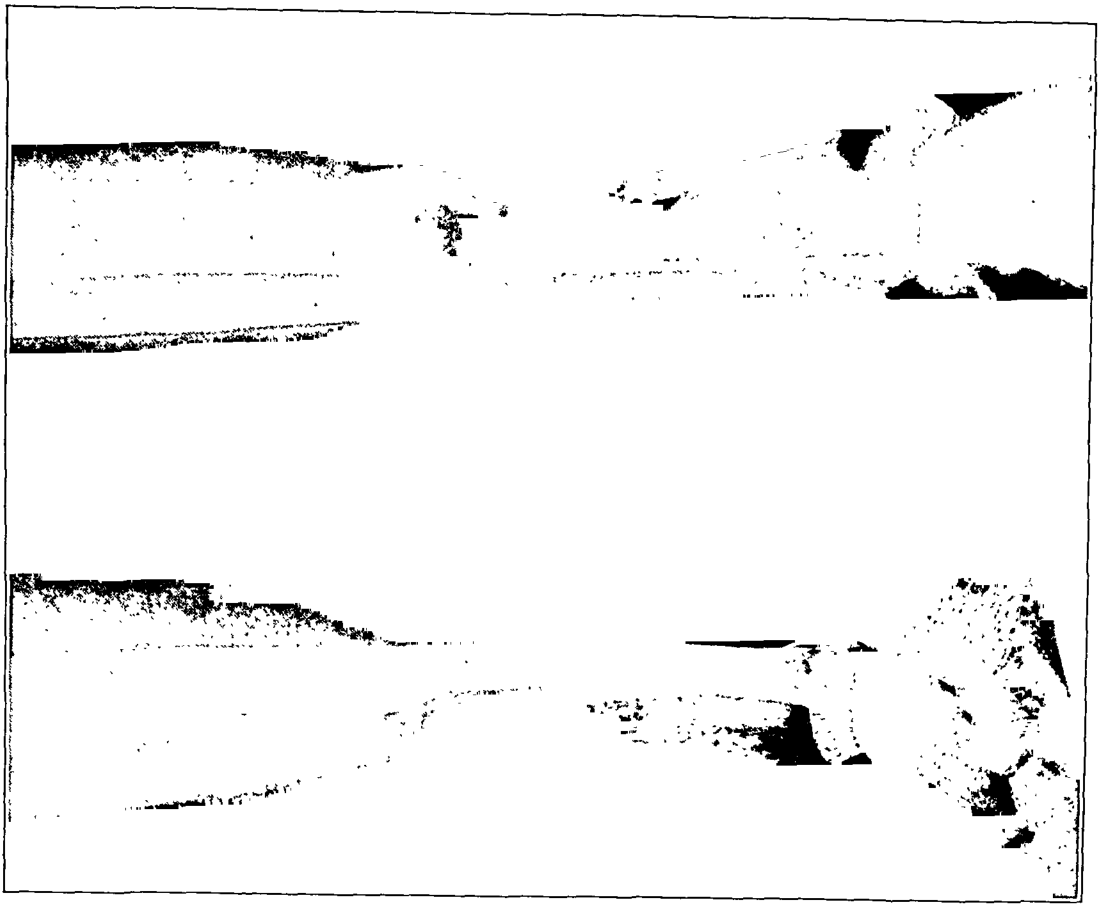

Fig. 5-B

End result six months after overzealous débridement and removal of all bony fragments. Notice complete loss of tibial shaft and small rarified areas of osteomyelitis. A persistent draining sinus delayed bone reconstruction. Amputation was advised.

infection persists for a long time. Thus bone-graft or reconstructive procedures are delayed until long after the time in which the fragments would have fused of themselves, and would have formed an entire, or at least a partial, new shaft. Often, after such radical removal of fragments, amputation is the only means to rehabilitation.

Non-metallic foreign bodies which are readily accessible should be removed, but a search for all metallic particles is unnecessary, and may do more harm than good. Many metallic particles are deeply buried in muscle and rapidly become walled off, after which they cease to prevent healing (Figs. 7-A, 7-B).

After a conservative débridement, a fine mesh gauze pack, heavily impregnated with vaseline, should be loosely inserted at the bottom of the wound, thus facilitating drainage. Fortunately, in most cases, drainage is slight and rapid wound healing occurs. If the wound is packed tightly, the formation of pus pockets may destroy the many viable bony fragments, and non-union with osteomyelitis may result. On the other hand, if loose packing is not inserted, the muscles and skin may heal superficially, closing the wound prematurely. Deep-tissue infection with pus retention may result and be extremely serious.

The affected parts should be completely immobilized for a long period, and, occasionally, traction in plaster is necessary to maintain the length of the bone. Changes of cast should be infrequent, to obviate the danger of breaking or disturbing the delicate callus and bony struts which form in a surprisingly short time. If these are broken or if lateral stress is placed upon them, non-union may result.

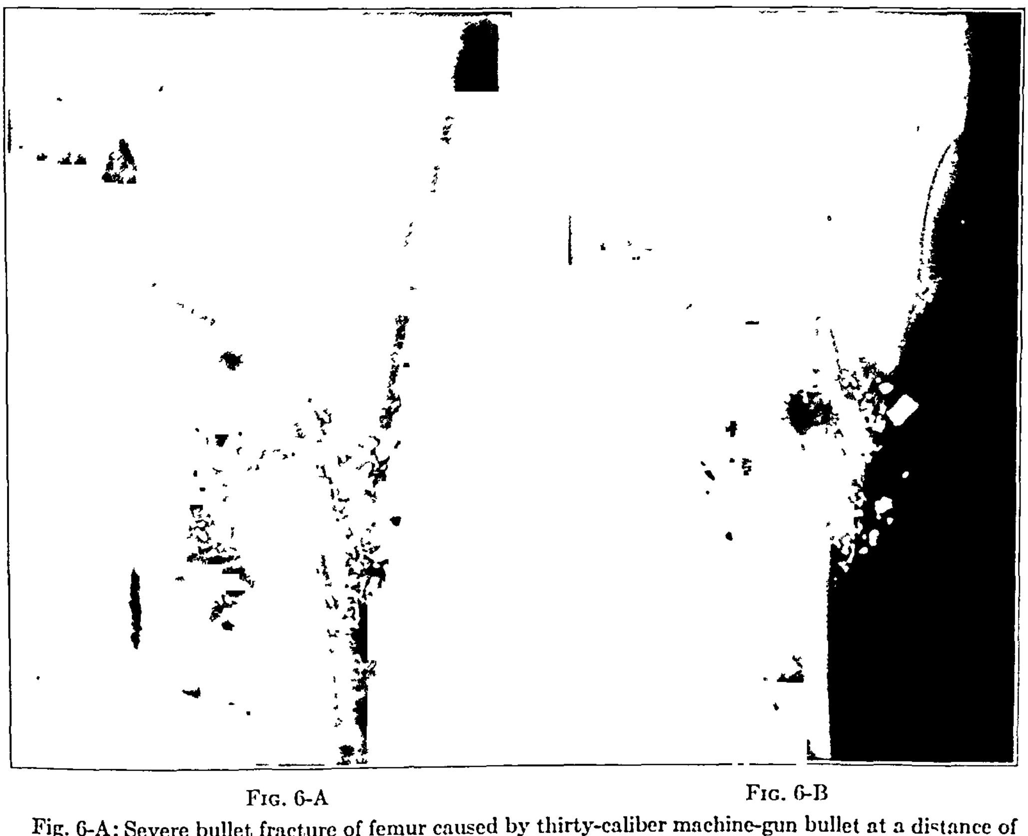

FIG. 6-A FIG. 6-B

Fig. 6-A: Severe bullet fracture of femur caused by thirty-caliber machine-gun bullet at a distance of three feet.

Fig. 6-B: Roentgenogram taken ten months later shows the enormous reconstructive power of these shattered fragments of bone if left alone, in spite of the presence of metallic particles in the soft tissues. Wound has healed but for a pea-sized sinus. Patient has walked for the last six weeks in walking caliper brace.

Fig. 7-A

Fig. 7-B

Fig. 7-A: Fresh bullet fracture of ulna, caused by fragments of German shell.

Fig. 7-B: Roentgenogram taken *after five and a half weeks shows wounds healed; fractures clinically solid* in spite of the metallic fragments in the tissues.

A few illustrations selected from a large series of patients are presented to show the tremendous restorative powers of bone healing and reconstruction of which Nature is capable, if not interfered with unwisely. Amputation of many extremities has been avoided by the recognition of these principles.

THE INTERVERTEBRAL DISC: ITS MICROSCOPIC ANATOMY AND PATHOLOGY

Part II. Changes in the Intervertebral Disc Concomitant with Age

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In a preceding article[3] we presented the first of three studies on the intervertebral disc. The purpose of these studies and the methods and material used were explained. The anatomy, embryology, and physiology of the intervertebral disc were reviewed, our own specimens being used to substantiate or disprove the accepted ideas along these lines. The present paper deals with the microscopic changes observed during the aging process.

The body passes through a degenerative cycle which is reflected in all its tissues. This change, which is part of the aging process, begins even at birth. During the earlier years of growth and development, these degenerative or retrogressive changes are insignificant as compared with progressive or developmental changes. But, as growth slows down, retrogression speeds up, and in later years finally dominates. All the body tissues are affected by these downhill changes, some much more than others. The intervertebral discs, of course, follow this pattern of progression and retrogression. It is evident that they are affected early and retrogress more rapidly and severely than do most of the other tissues. This is usually explained on the basis of excessive wear and tear. At all times, the intervertebral discs are actively functioning. They are subject to a great deal of traumatic insult. Their constant use, as well as their susceptibility to trauma, and their relatively poor blood supply, doom the intervertebral discs to early and advanced degenerative changes. The following changes have been observed in the respective decades.

FIRST DECADE

In the first decade of life many developmental changes take place. The intervertebral discs are in a stage of progression, not of retrogression. Five specimens have been studied from subjects ranging in age from ten months to seven years. Changes will be recorded under the three headings: cartilaginous plate, annulus fibrosus, and nucleus pulposus. Figure 1 represents a typical disc of this first decade.

A. *Cartilaginous Plate*

The cartilage cells are round to oval and very clear microscopically. They are hyaline in type. The matrix stains deeply and is homogeneous. The cartilaginous plate itself extends over the entire end surface of the vertebra, and downward anteriorly and posteriorly for a short distance.

Up to the age of six years the specimens show hyaline cartilage dipping into the bodies of the vertebrae. In the ten-month specimen there is complete sagittal separation of the posterior sixth of the body from the remaining anterior portion by a band of cartilage extending between the two cartilaginous plates. Ossification is present along its vertebral margins, which is actually the epiphysis of the vertebral arch. It gradually decreases in size to thin out and disappear by the tenth year.[9]

At the edge of the cartilaginous plate, adjacent to the cancellous bone of the vertebrae, is the ossification layer, in vertical rows of columnar cells. Here endochondral growth of the vertebral body takes place. The inner margins of this layer are wavy in outline. Here and there (Fig. 2) are "ossification gaps", the importance of which has been empha-

FIG. 1
Intervertebral disc of a boy, aged six years. *a.* Section (× 6). *b.* Roentgenogram.

sized by Schmorl. He expressed the belief that they correspond to the perforations in the end plate, as previously described. These gaps occur most commonly at about eight years of age and have horizontal bands of fibrillated cartilage matrix running across them. In the adult, all evidence of these gaps disappears, but they may be weak points, first affected by stress and strain.

In the very early ages, *numerous vascular channels* are seen imbedded in and perforating the cartilaginous plates from the vertebral side. By the age of ten years, these channels have largely disappeared, though they may remain to the age of twenty years.[1] Übermuth in 1929 and Böhmig in 1930 were the first to stress the importance of these vessels. The specimens in this study confirm the fact that the origin of these channels is the spongiosa. Fi-

FIG. 2
Photomicrograph (× 115) showing portion of an intervertebral disc of a girl, aged seven years. *A:* Ossification gap. *B:* Ossification layer of cells. *C:* Cartilaginous plate.

brosis, followed by invasion by cartilage cells, obliterates these channels at an early age. Scars of these channels remain throughout the life of the disc. These obliterated channels may be areas of weakness, predisposing to herniation of material from the nucleus pulposus.

Evidence of congenital or developmental defects in the cartilaginous plate is lacking in this study. The ossification gaps and vascular channels already mentioned are the only factors found predisposing to nuclear protrusion. No true splits or open defects have been found. The fact that they are found in later life may be accounted for on the basis of artefacts. (In the spinal columns of young subjects, the cartilage and bone are soft, allowing easier section with the microtome knife than in older specimens; consequently there is less crushing and tearing.)

FIG. 3

Roentgenogram of vertebrae and intervertebral disc of same subject as Fig. 2. *A:* Ring containing cartilaginous epiphysis.

Schmorl stated that ossification centers appear in the epiphyseal ring as early as the eighth year. The epiphyseal ring could be seen roentgenographically, in one of our specimens from a subject, aged seven years (Fig. 3). The superior and inferior anterior vertebral margins are characteristically notched.

B. *Annulus Fibrosus*

Übermuth has expounded the hypothesis that the components of the intervertebral disc grow and change according to the stress and strain brought on by the changes in age, with resulting changes in function. Thus, the annulus has developed by the age of six months, for the child is beginning to sit up and needs the spinal column for support. Our earliest specimen, that of a ten-month-old infant, shows the annulus quite well developed (Fig. 2, Part I).[3] The fine strands of fibrous connective tissue with their long, narrow nuclei are arranged in bundles or lamellae, running for the most part parallel, but in places interwoven.

As the age of the subject increases, the annulus begins to attach itself to the newly developing anterior and posterior longitudinal ligaments. Stress and strain begin their formative function and the lamellae take a slightly different course as they stream off of the cartilaginous plate. The open spaces between the lamellae fill up with a ground substance, and by the tenth year the annulus has completely developed as a compact, retaining structure.

C. *Nucleus Pulposus*

We must always think of the nucleus pulposus as an active, living structure vitally concerned with body mechanism. During the first decade the nucleus develops rapidly. Chordal remnants—cells and gelatinous matrix—tend to disappear. Most authors describe the presence of chordal cells,—large, pale-staining, multinuclear cells with vacuolated cytoplasm. (None of these cells was found in the specimen from the ten-month-old subject.) Fibroblasts in large numbers are seen, as well as cartilage cells, especially around the periphery.

The shape of the nucleus in the specimens from very young subjects is more rectangular than oval. As the subject grows older, however, the oval shape is assumed. The fine, interlacing fibrils in their delicate ground substance of amorphous, mucoid material seem to grow coarser toward the end of the first decade. Vacuoles in large numbers occur, as well as large, irregular spaces in the nucleus. These spaces are often thought of as central cavities, analogous to joint spaces. No evidence of endothelial lining has

FIG. 4
Intervertebral disc of a youth, aged sixteen years. *a.* Section (× 4). *b.* Roentgenogram.

been observed, although an acellular, flattened, darker-staining lining is often present. This may be due to deposition of stain or to the concentration of amorphous material contained in these cavities. Saunders and Inman expressed the opinion that these cavities are probably evidence of desiccation of the nucleus. Our study tends to support this view. In fact, the cavities may be only artefacts.

Is there true mucin in the nucleus pulposus of the intervertebral disc? Deucher and Love, among others, have found evidence of mucin in posterior protrusions of a disc removed at operation. They used mucicarmine stain to demonstrate it. De Galantha's mucin stain was used in the present study. No section showed the presence of mucin with this stain, though there is a characteristic bluish reaction in the nucleus pulposus to hematoxylin and eosin which certainly suggests that the ground substance of the nucleus is a mucoid material.

SECOND DECADE

In the second decade progressive changes are still occurring, but in the later years the picture of the adult disc is reached. Figure 4 shows a typical disc of this period.

A. *Cartilaginous Plate*

Growth of bone continues from the base of the cartilaginous plate, although it has slowed up a great deal toward the end of this decade. After the age of fourteen to sixteen years, the cartilaginous plate rapidly becomes less active than before. At the age of twenty years, only very few cells of endochondral growth are found. The ossification gaps persist as long as ossification continues. An increase in the deposition of bone at the vertebral bony end plate is found during the middle of the second decade.

A specimen from a youth, aged nineteen years, shows fusion of the epiphysis to the body of the vertebra. However, in none has a section included an ossification center in

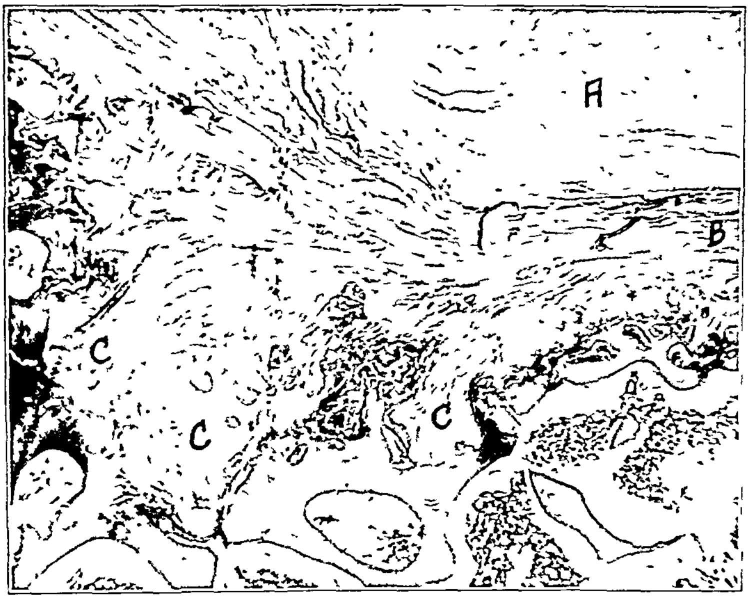

FIG. 5

Photomicrograph (× 25) showing portion of an intervertebral disc of a youth, aged twenty years. *A:* Nucleus pulposus. *B:* Cartilaginous plate. *C:* Multiple nuclear protrusions.

the epiphyseal ring. The cartilaginous plate in the specimens from younger subjects extends to the edge of the vertebra anteriorly and posteriorly, but after fusion of the epiphysis to the body, the cartilaginous plate ends abruptly at the edge of the epiphysis, and annulus fibers stream over the bony rim formed by the ossified epiphyseal ring, to insert into the longitudinal ligament and into the vertebral bone itself.

Many vascular channels are still present. They are seen to be filled with blood and penetrate deeply into the cartilaginous plate. These channels diminish as age progresses and none of the specimens in this study beyond the age of nineteen years shows them. The scarring of these channels has been described previously.[3]

During this decade the cartilaginous plate has become somewhat thinner than before, and the cells have taken on a more mature appearance. The ossification of the plate has almost stopped. The cartilaginous plate has fused anteriorly and posteriorly to the epiphyseal ring. In all, it has reached its maturity and almost the end of its phase of progression and development.

Retrogression has taken place during this decade. Perhaps the curves of progression and retrogression cross at about the age of eighteen years, when the two are at a balance. At least, from this decade on, degenerative processes advance rapidly. No true Schmorl's nodules were found in our specimens before the age of twenty years. One specimen, from a male subject, shows some multiple microscopic protrusions (Fig. 5), one of which can be seen grossly. Most of them are found at the peak of the expansion of the nucleus, a point that will be discussed later.*

Several longitudinal fissures are seen in the cartilaginous plates in this decade. They are probably artefacts, not to be mistaken for congenital defects, although Beadle expressed the belief that they may be developmental.

Roentgenograms of these specimens are all normal except for the previously mentioned twenty-year-old male subject. This is a good example of a nuclear expansion and also of a Schmorl body. No hypertrophic lipping is evident in any roentgenograms in this series during the first two decades; also no thinned discs are observed.

B. *Annulus Fibrosus*

Progression is probably still taking place in excess of retrogression in the annulus fibrosus of this decade. As stress and strain are applied to the disc during the vigorous activity of youth and young adulthood, the annulus must be further strengthened to serve its purpose as a limiting structure for the nucleus pulposus. Whereas during the first decade of life the fibers were more discrete and the lamellae tended to be separated

* In Part III, to be published.

from each other by slight gaps, in this decade the lamellae are tightly packed together, functioning more as a whole. Growth of annulus fibers from the cartilaginous plates has progressed, and there is more annulus superiorly and inferiorly between the nucleus and the cartilaginous plate.

The epiphysis has fused, in many instances, to the underlying vertebrae in the latter part of this decade. The annulus fibers, in these cases, have anchored themselves to the bony rim of the epiphysis; some have passed over it, merging with the longitudinal ligaments.

In the later years of the second decade, however, there is evidence of degeneration. The fibers comprising the annulus become less distinct; the number of nuclei seems to decrease; and early hyalinization can often be observed.

C. *Nucleus Pulposus*

Development is still taking place in the nucleus pulposus during the second decade. The fluid content is increasing as the nucleus responds to its increased functional rôle. The loss of the diffuse character of the nucleus is noticeable. Whereas during the first decade the nucleus is a general admixture of cells, fibrils, and semigelatinous ground substance, it now becomes more broken up and irregular. A central cavity sometimes appears. This cavity does not have a cellular lining and is probably central debris lost during sectioning, though some writers look on it as a rudimentary joint space.

Around the periphery the nucleus becomes somewhat more cellular,—chiefly cartilage cells, in pairs and in nests. Fibrils remain in the nucleus but they are seen in clumps. Parts of the nucleus have a new granular appearance. Vacuoles are still seen. The line of demarcation separating the nucleus from the annulus becomes somewhat more distinct during the second decade. This is another indication that the differentiating process is taking place and that the nucleus is maturing and growing to its adult functioning form.

THIRD DECADE

In this group of eight there are two specimens which showed evidence of disease. One, from a twenty-nine-year-old woman, shows roentgenographic as well as gross evidence of definite thinning of the disc. The other, from a thirty-year-old man, is a classic example of a nuclear expansion. (These two cases will be discussed in Part III.) Figure 6 represents a typical disc of this decade.

A. *Cartilaginous Plate*

Developmental changes are still going on at the beginning of this decade, but to a lesser degree. While there are a few islands of bone-forming cells at the base of the cartilaginous plate, it has for the most part ceased its growth function. The epiphyses that have not already united do so at the beginning of this decade.

What retrogressive changes are taking place? The processes of wear and tear, of repeated trauma, begin in earnest during the active period of young adulthood. Degenerative age changes, *per se*, are commencing. However, the changes are early, and microscopic evidence is not abundant. A few specimens do show beginning fibrillation of the cartilage. Also, longitudinal fissures are occasionally seen. These, for the most part, are probably artifacts; though they may occasionally be results of trauma. They do not, as a rule, show evidence of repair. A few specimens, however, do show fibrous invasion, proving that some of these fissures are premortem. These repaired tears are seen best with the van Gieson stain.

The cartilage cells during this decade show occasional signs of degeneration, though for the most part they are clear in outline and have normal nuclei. The width of the cartilaginous plates seems slightly less than before, as suggested by Donohue, though this is hard to evaluate. A few remaining vascular channels are seen in some of the speci-

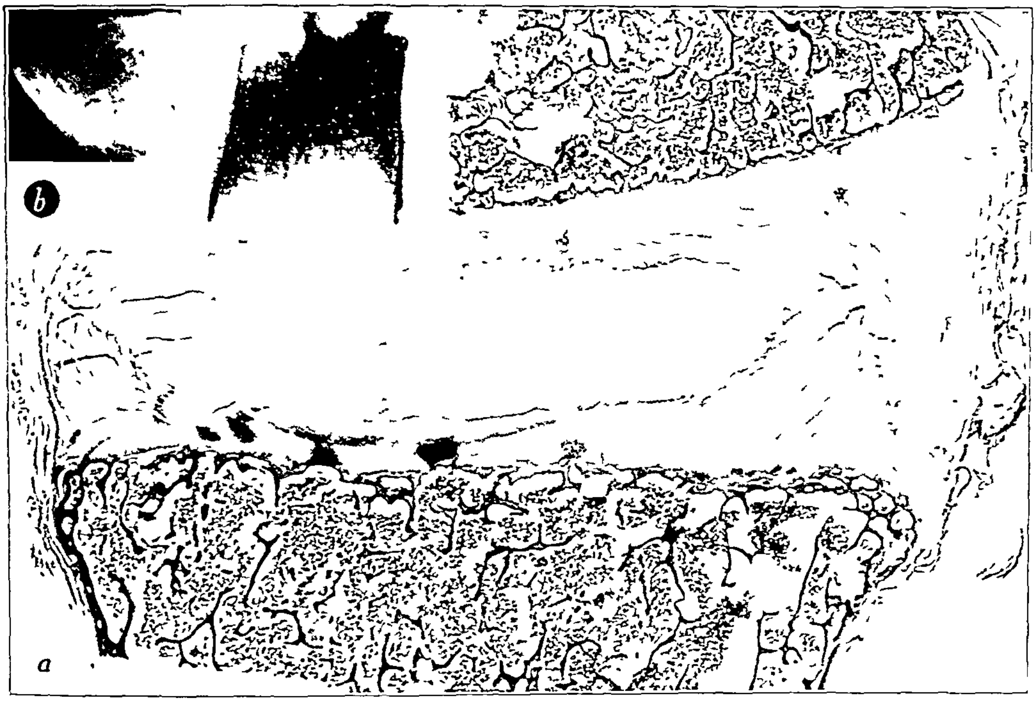

FIG. 6

Intervertebral disc of a woman, aged twenty-one years. *a.* Section (× 4). Most of the nucleus pulposus has dropped out during sectioning. *b.* Roentgenogram.

mens of this decade. The zone of calcification at the junction between cartilage and bone is becoming more distinct than it was earlier.

Only two of the eight specimens in this group show evidence of breaks in the cartilaginous plate with protrusion of nuclear material through the breaks. These breaks are seen in increasing number as age progresses, and are a definite indication of the degree of the degenerative changes occurring in the disc. The microscopic protrusions of the nucleus pulposus into the adjacent vertebrae will be discussed in detail in Part III.

B. *Annulus Fibrosus*

During this decade the changes accompanying wear and tear seem to appear to the greatest extent in the annulus. The fibers become coarse and hyalinized, and a concentric fissuring of the lamellae occurs. Cellular detail is almost lost. One specimen in this group shows a moderate amount of oedema between the lamellae.

Deucher and Love, examining specimens of protruded discs removed at operation from patients of various ages, found degeneration of cartilage cells in 32 per cent. This was demonstrated by loss of cell outline and pyknosis of the nuclei. The specimens studied in this decade alone show at least this high a percentage of degenerative changes in the fibrocartilage cells of the annulus.

C. *Nucleus Pulposus*

The nucleus is no longer mucoid in appearance. The general composition is of several cavities of various sizes, in a loose, fibrillar network. At the periphery are heavier fibers and many more cartilage cells than were seen in the previous decade. Some of these nests contain ten to fifteen cells. The nucleus begins to blend more intimately with the annulus, as stressed by Saunders and Inman. During the first decade the two were indistinct. During the second decade, the nucleus seemed to differentiate and separate

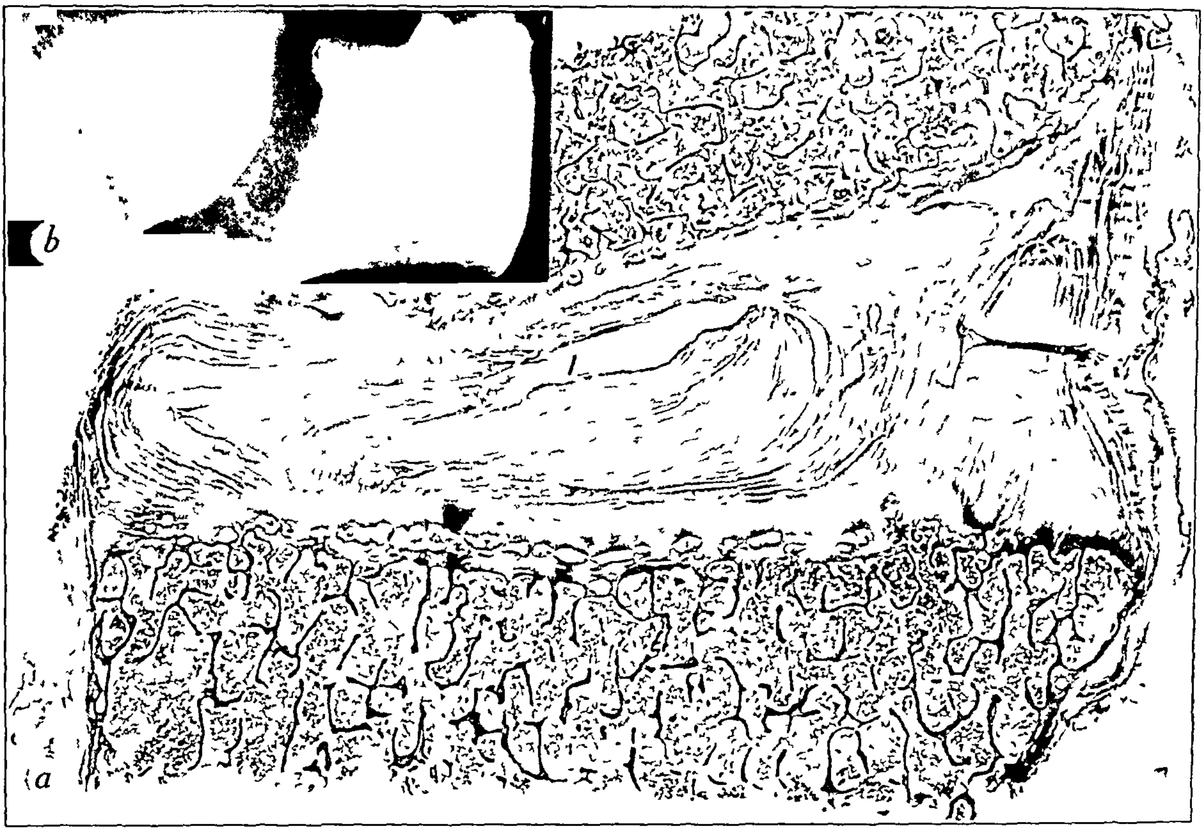

Fig. 7

Showing intervertebral disc of a woman, aged thirty-five years. *a*. Section (× 4). *b*. Roentgenogram.

from the annulus. But during the latter part of this third decade, it is again no longer distinct from the annulus.

According to Übermuth's hypothesis of adaptation, during the third decade the disc is at its maximal point of function. Beadle quoted Übermuth as follows: "At this stage the disc has a uniform soft buffer action and elasticity; it is the high-water mark of the swelling process and from then onward there is the steady loss of fluid characteristic of age".

FOURTH DECADE

Nine specimens were examined in this group. One showed thinning, one showed nuclear expansion, and five showed microscopic evidence of nuclear protrusions into the spongiosa of the vertebral body. Thus we see that pathological lesions are increasing in number and keeping pace with the degenerative changes of age. Figure 7 represents a typical disc of this age group.

A. *Cartilaginous Plate*

It is very striking to see the severe retrogressive changes that have occurred in this decade. The degenerative defects in the cartilaginous plate range from thinning to complete absence of cartilage in places. Many microscopic protrusions of the nucleus pulposus are evident. In several places there is evidence of bony invasion of the cartilaginous plate from below, with blood channels and marrow elements penetrating into the nucleus. This erosion from the marrow spaces has been described in detail by Saunders and Inman.

The cartilage has lost its even texture in this decade and for the most part takes a rather mottled, irregular stain. There is a definite increase of deposits of calcium salts at its base. Fibrillation is more evident and in places almost completely destroys the normal cartilage.

Why defects in the cartilaginous plate—fissures and tears through which nuclear material extrudes—should appear at this age has been a point of controversy. Donohue

expressed the belief that the cause is a congenital fault, plus a tear from trauma. The only congenital fault that we have been able to demonstrate, however, is the blood vessel channels that penetrate the plate in the first decade and later sclerose. These, we feel, are the chief regions of weakness, at which in middle age protrusion may occur from trauma.

B. *Annulus Fibrosus*

Degenerative changes are more marked during this decade than at earlier ages In addition to fissuring, hyaline degeneration, increase of nests of cartilage cells and nuclear pyknosis, two new phenomena appear. One, that of pigmentation, is seen in one of the specimens of this group. The pigment is finely granular and takes a reddish-brown stain with hematoxylin and eosin and a yellow stain with van Gieson's. It is arranged in long oval streaks between the lamellae. Its exact composition and nature are unknown but, since it makes its appearance as age progresses, it is probably a result of degeneration.

The second change to make its appearance in this decade is that of vascularization of the annulus. This was first observed in this study in a specimen from a woman, aged thirty-five years (Fig. 8). Several small thin-walled blood vessels were imbedded in the medial layers of the posterior portion of the annulus. They were grouped together and their lumina were filled with blood cells. This invasion of the fibrocartilage of the annulus by blood vessels may be an attempt on the part of the body to strengthen and nourish a structure which has become weakened and degenerated.

FIG. 8

Photomicrograph (× 145) showing blood vessels in the posterior portion of the annulus fibrosus of a woman, aged thirty-five years.

C. *Nucleus Pulposus*

The gradual loss of fluid in the nucleus has been described in detail by Puschel. This loss of fluid is evident microscopically The soft, lacy appearance of the nucleus has given way to a mass of fibrous tissue and cartilage cells. During this decade the replacement of the nucleus with fibrous tissue is very evident. Only in occasional sections can one see the remains of the semigelatinous ground substance and the fibrillar reticulum. The distinction between the nucleus and the annulus has become less marked than it was. It appears as though the body were attempting to make the disc one solid fibrocartilaginous mass. Several of the sections show a loss of the center of the disc. This has probably fallen out during preparation,—an indication of the crumbly, dry nature of the nucleus.

FIFTH DECADE

There are eleven specimens in this group. Of these eleven, four showed evidence of disease. There is an example of "ballooning", one of thinning, one of nuclear expansion,

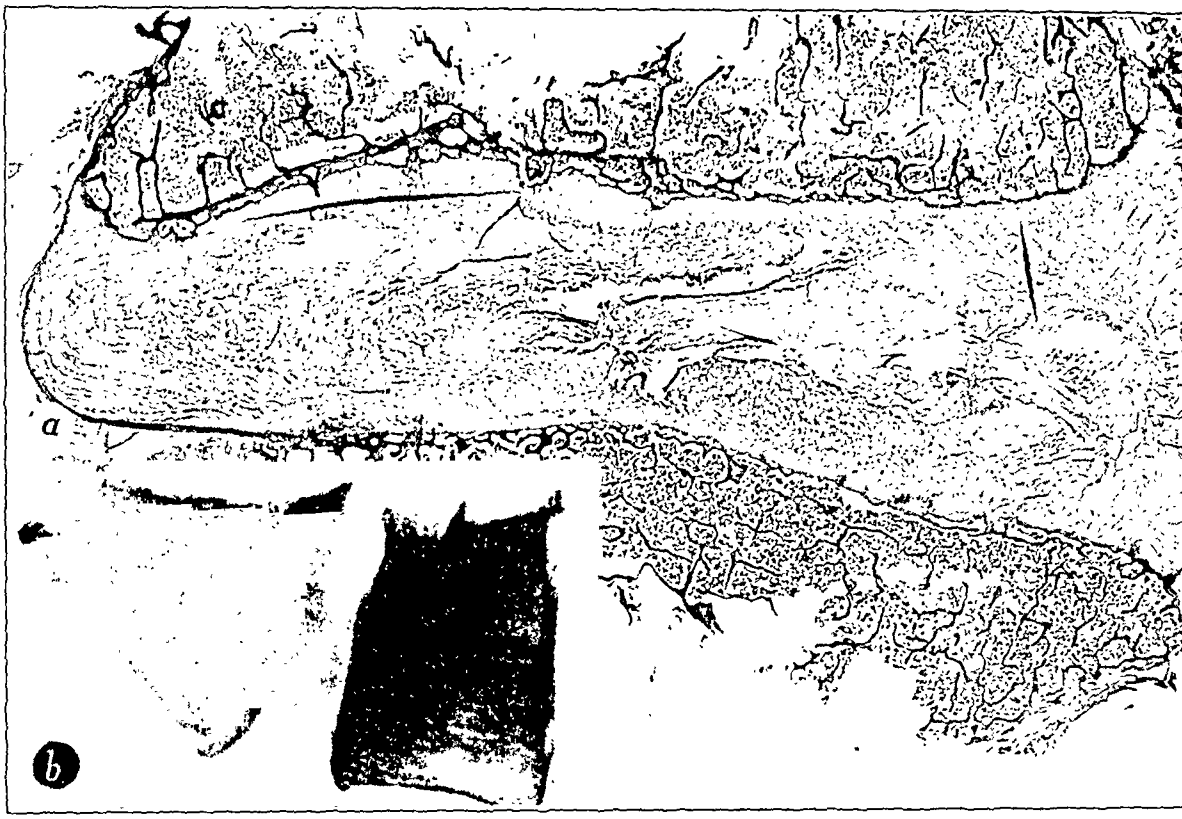

FIG. 9
Intervertebral disc of a man, aged forty-five years. *a.* Section (× 3.5). *b.* Roentgenogram.

and one showing a Schmorl body large enough to be seen with the naked eye. In addition, eight of the eleven specimens have defects of the cartilaginous plate with microscopic prolapse of the nuclear material into the body of the vertebra. Figure 9 represents a typical disc of this decade.

A. *Cartilaginous Plate*

One is struck by the advanced degeneration of the cartilaginous plate in this group. There is hardly one that anywhere approximates the appearance of a cartilaginous plate in the younger-age groups. Most conspicuous, perhaps, is the number of microscopic protrusions of disc substance through defects in the plate. These protrusions can be seen just entering the cartilaginous plate or may be at any stage in penetration. Very few go deeply into the bone, usually stopping at the bony plate. These protrusions suggest that the cartilaginous plate is losing its resistive power.

Besides protrusion of the nucleus, there are numerous examples of erosion of the cartilaginous plate by the bone marrow. These marrow erosions may extend well into the nuclear substance but usually stop somewhere in the plate. What determines the direction of the protrusion—from the disc out, or from the vertebrae in—must depend chiefly on the existing forces on each side of the cartilaginous plate. This balance must be determined in turn by the amount of turgor in the nucleus pulposus, for the potential force of the marrow spaces is probably constant.

Fibrillation of the cartilaginous plate is rather marked in several specimens. One specimen exhibits advanced oedema and loss of cellular outline. As a rule, however, the cartilage cells are still quite normal in appearance.

Numerous clefts and fissures are found in specimens from this decade. The majority are probably artefacts. Some are definitely antemortem, however. One specimen (Fig. 10) shows a zigzag vertical tear, filled with fine fibrinous material and a few fibroblasts. Such proved tears—proved by evidence of repair on the part of the body—are rare.

Variations in thickness of the cartilaginous plate are rather striking in this decade. In some regions the plate is entirely gone. Is this an acquired defect or a defect in development? Probably the former, as it is not observed in our younger specimens. At these points of thinness or absence, the nuclear material may or may not have protruded into the underlying bone.

Fig. 10

Photomicrograph (× 70) showing healed tear in cartilaginous plate of man, aged forty-three years.

B. *Annulus Fibrosus*

Degenerative changes continue to progress. Hyalinization is well advanced in many specimens. The lamellae are blended together in a nondescript, fibrous mass, their outlines being mere shadows. Pyknosis and even disappearance of the nuclei are common. Many of the fibrils are short, thick, and swollen. In fact, several of the sections show oedema fluid in small vacuoles scattered through the annulus.

There are many regions of new cartilage cells. Whereas in the preceding sections they were all in groups or "pearls", in some sections in this decade they are in columns, corresponding in direction to the lamellae.

Fissuring of the annulus is conspicuous. Occasional new blood vessels are seen, as in the preceding decade, but this is by no means common. Many of the sections have lost the anterior fibers of the annulus in preparation. The posterior fibers, however, are intact. No posterior nuclear protrusions are seen in this decade.

C. *Nucleus Pulposus*

The confines of the nucleus can still be distinguished in most cases in this group. However, the distinction is fast becoming less and less apparent. A gradual fibrous replacement of the nucleus is going on. The typical section in this decade shows the nucleus to be of almost the same consistency as the annulus, except that here and there are remnants of the fibrillar reticulum. The fibrous cells, of course, are not arranged concentrically as in the annulus, but pass through the nucleus in an apparently indiscriminate fashion.

More cartilage cells in groups are seen than at earlier ages. One rather marked change is the amount of amorphous debris, both in clumps and finely scattered throughout the nucleus. Many sections show pigment, as first observed in the preceding decade. Oedema is present in a few cases. While there is still evidence of a semigelatinous consistency to the nucleus, this is fast disappearing as the nucleus becomes replaced by fibrous tissue, cartilage, and amorphous material.

SIXTH DECADE

It was in this decade that Deucher and Love found the greatest amount of degeneration in specimens of protruded discs removed at operation. It is true that in the postmortem specimens reviewed in the present study the amount of degeneration had gradu-

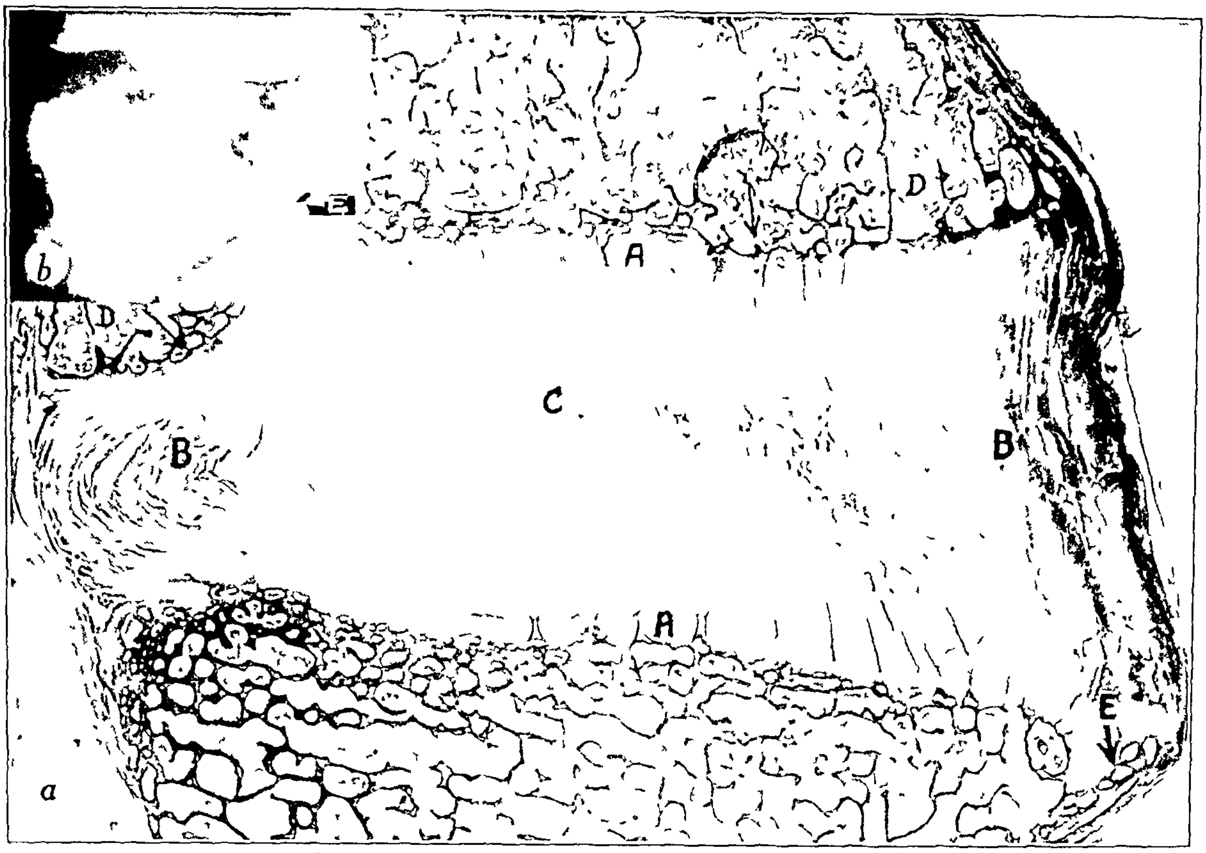

FIG. 11

Intervertebral disc of a man, aged fifty-four years. *a*. Section (× 3.25): *A*, cartilaginous plate, *B*, annulus fibrosus, *C*, nucleus pulposus; *D*, bony rim, the arrows indicate junction of the cartilaginous plate and the bony rim, *E*, bony spur. *b*. Roentgenogram

ally increased until at this decade it is more advanced than in any preceding decade.

Of the twenty-two specimens in this age group, eighteen have demonstrable defects of the cartilage with nuclear protrusion. In addition, three specimens showed microscopic evidence of posterior protrusion of the disc. Three specimens showed thinning of the disc, substantiated by the roentgenographic appearance. In two cases Schmorl bodies were seen in the gross. There were one case of "ballooning" and one case of nuclear expansion. In several cases there was evidence of hypertrophic lipping. These will all be discussed in Part III, but they show that the curve of the incidence of diseased discs rises with the increase in age. A disc typical of this decade is represented in Figure 11.

A. *Cartilaginous Plate*

The most striking characteristics of the cartilaginous plate in the sixth decade are evidence of old, calcified, "healed" nuclear protrusions through the cartilaginous plates; heavy deposits of calcium; and advanced destructive and degenerative changes in the hyaline cartilage comprising the plate.

Rarely does a disc not show several defects in the plate through which nuclear material has streamed. Calcification is the most common defect seen at this age. The protrusion is composed of old cartilage cells, some fibrous tissue, a few blood vessels, and much calcium salt. These defects often have bone marrow growing into them from below, meeting the cartilage that has replaced the nuclear material. There are also a few recent protrusions into the spongiosa, usually small, and occurring most commonly near the border between the epiphysis and the cartilaginous plate, some actually penetrating well into the bony rim.

Calcium is deposited in large plaques and masses in the old protrusions, as mentioned

Fig. 12-A

Photomicrograph (× 3.5) showing intervertebral disc of a man, aged seventy-one years.

previously. Occasionally it is directly in the cartilaginous plate, but usually it occurs along the junction of the plate and the bone itself. This deposit appears to show the age of the disc as much as any one factor. Its amount is consistent with increasing age.

The nuclei of the cartilage cells are showing more and more pyknosis, karyorrhexis, and karyolysis. The cells tend to lose their distinct outline and stain irregularly. Fibrillation is common and there is actual necrosis in places. Several healed tears are evident.

B. *Annulus Fibrosus*

There is no type characteristic of this age group. Degeneration of the annulus has merely progressed. The average section viewed grossly reveals narrowing and compression of the posterior fibers of the annulus. The junction between the annulus and the nucleus is becoming less and less distinct

Fig. 12-B

Roentgenogram of intervertebral disc shown in Fig 12-A

The annulus appears to be broken posteriorly in a high percentage of cases in this decade Six of the twenty-two slides show invasion of the annulus and nucleus with whorls of new, deeply staining fibrous tissue, and small blood vessels. This invasion occurs in those slides that show posterior breaking and destruction of the annulus In a few cases the disc protrudes

posteriorly through these tears. The invasive elements must be interpreted in the same light as the protrusion into the vertebrae,—namely, an attempt on the part of the body t plug and rebuild the damaged disc tissue.

Other changes seen in this group are plaques of calcium, seen in the anterior annulu in two specimens; advanced hyalinization of the lamellae; small localized areas of necrosis and cross and concentric tears. The lamellae are enlarged but their definite outline i less distinct and they tend to blend somewhat together.

C. *Nucleus Pulposus*

At this decade the nucleus so resembles in composition the annulus that most of th foregoing applies to it as well. The trend toward a blending of the fibrocartilaginou elements of the annulus and nucleus is progressing. The nucleus in this decade is almos completely fibrocartilage. Seen in an advanced degree, however, is the occurrence o amorphous material. This is of two types: large, coarse, localized clumps of amorphou matter; and fine strands of finely granular material, running parallel to the fibrous bundles The larger clumps probably represent the end stage in necrosis and dehydration of th nucleus. The fine, granular material is similar to the brown degeneration and pigmentation described by Beadle, Saunders and Inman, Donohue, and others.

Large, longitudinal clefts run through many of the discs. These are seen most ofter where there is posterior protrusion. In these cases, the nuclear material is lost posteriorly, and the fissure remaining is the space formerly occupied by this material. In a few others the clefts are oblique, running down to nuclear protrusions that have occurred through the cartilaginous plate and into the adjacent vertebral bone.

SEVENTH DECADE

Thirteen of the twenty-seven specimens in this last group show definite evidence of disease. The changes of degeneration and trauma are rather extensive, although a few exceptions to this are seen. (One disc shows no more degenerative changes than one would expect to find in a thirty-year-old subject.) Figures 12-A and 12-B represent a disc typical of this age group.

A. *Cartilaginous Plate*

There is no specific change in the cartilaginous plate during this decade, simply a progression of the previously noted degeneration. The cartilage cells are less numerous than at earlier ages, and their nuclei are pyknotic. The cartilage matrix is pale and irregularly staining, and fibrillation has occurred in most cases. Longitudinal bands of fibrous tissue are seen in many places. Bands and small plaques of calcium are also evident, some imbedded deeply in the cartilaginous plate; most of them, however, are working up from the peripheral zone of calcification. In places the cartilage is replaced entirely by bone invading from below.

Defects are extremely frequent. In only one section in this group were microscopic protrusions not apparent. These protrusions are for the most part calcified, and in many instances they are bony in composition. Erosion of the cartilage by the marrow and bone is a very frequent picture. In fact, there are two specimens in this group that show hardly any remaining cartilaginous plate, since it has been replaced by bone from the adjacent vertebrae.

The junction between the hyaline cartilage of the plate and the fibrocartilage of the annulus is indistinct in these later years. The "streaming off" of the fibrocartilage from the cartilaginous plate is hard to see, and there is a blending of all the disc substances.

B. *Annulus Fibrosus*

The annulus in this end stage of retrogression and degeneration is in most cases still relatively intact. It is not functioning in the same capacity as in the younger groups,

in which the nucleus is semiliquid, and the annulus tends to hold in and distribute the potential forces of the nucleus. Among these older persons the stress upon the annulus is not so great as among young persons. Tears in the annulus are seen often, though most of them are old, as evidenced by the amount of repair which has taken place in the way of invasion of blood vessels and fibrous tissue. Some of the vessels penetrate well into the nucleus. They enter most commonly posteriorly, where more tears occur, but there are some examples of anterior invasion.

The fibers composing the annulus have reached a stage of advanced degeneration. They are hyalinized, torn, and in places necrotic. Strands of fine pigment can often be seen parallel to and between the lamellae. There are many groups of cartilage cells and some localized regions of calcification. In one instance, a region of new bone had developed in the posterior portion of the annulus.

C. *Nucleus Pulposus*

Even at these later years of life there is evidence of the mucoid ground substance with its included fibrillar strands, as seen in the younger specimens. Generally one is impressed, however, with the complete loss of all structure in the nucleus. Large spaces run horizontally,—evidence of desiccation. Many of the sections show nothing but masses of amorphous material where the nucleus is usually situated. Cartilage cells are very common, either in nests or diffusely scattered throughout the nucleus. In two sections bone had grown in from the adjacent vertebrae and had penetrated the nucleus pulposus. Most of the nucleus pulposus from these older patients, however, is composed of fibrocartilage.

One of the discs in this group shows enough calcium in the nucleus to be visible by roentgenographic examination. This will be discussed in a subsequent study. However, many simply show small plaques of calcium imbedded in the nucleus and visible only microscopically.

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UNCOVERTEBRAL OSTEOPHYTES AND OSTEOCHONDROSIS OF THE CERVICAL SPINE

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Neuralgic symptoms of the arms, neck, and back of the head are being referred in an increasing measure to affections of the cervical spine, the majority of which originate in the region of the intervertebral discs. Degeneration of the disc is often accompanied by loss of elasticity, eventually leading to structural changes in the adjacent vertebrae. It is in the cervical portion of the vertebral column, the site of greatest mobility, and also of greatest susceptibility to functional stress and trauma, that involvement of the discs is most common and particularly severe. Hypertrophic spondylitis or spondylosis deformans [marginal bony proliferations at the ligament attachments] is a frequent result of degenerative changes of the annulus fibrosus, the formation of osteophytes occurring as reparative manifestations. Arthrosis deformans [hypertrophic or degenerative arthritis] of the posterior articulations is a common accompaniment, the osteophytes of which may protrude into the intervertebral foramina, leading to vascular congestion and subsequent irritation of spinal roots and nerves.

The present paper deals with observations of forty patients, showing localized hypertrophic lesions, peculiar to the cervical spine and the first thoracic vertebral body, which the author terms "uncovertebral osteophytes", and which he believes may contribute to these symptoms.

ANATOMY

The full comprehension of the pathogenesis of the "uncovertebral osteophytes" is possible only if certain anatomical peculiarities of the cervical spine and the first thoracic vertebra are borne in mind. The thoracic and lumbar vertebrae have flat, smooth superior and inferior surfaces, the only exception being the upper surfaces of the first thoracic vertebra. Turner described the typical cervical vertebral body as follows: "The *body*, oblong in shape, the long axis being transverse, is small when contrasted with those of other regions. The superior surface has two well-marked lateral lips, which render it concave from side to side, while the anterior border is rounded off. The inferior surface is bevelled laterally, and thus is convex from side to side, while the anterior border is prolonged downwards to form a distinct lip. The lipped lateral margins of the superior surface rest against the bevelled edges of the inferior surface of the vertebra above, while the anterior lip of the inferior surface is in contact with the bevelled edge of the vertebra below, the thin intervertebral disc intervening in each case. The posterior surface is flat and bounds the spinal canal, while the anterior surface, also flat and rough, is situated at a slightly lower level than the posterior." The lateral lips of the superior surface of the bodies of the third to the seventh cervical vertebrae were called *processus uncinati* by Trolard, and *processus lunati* by Giraudi.

These elevations are easily seen in the anteroposterior roentgenogram of a typical cervical vertebra (Fig. 1).

Turner then proceeds to describe the pedicles of a typical cervical vertebra as "small and cylindrical, . . . directed laterally and backwards, and so arranged that the superior vertebral notch is deeper than the inferior, which, however, is broader—a result which is in part brought about by the lipped and bevelled lateral margins of the bodies which bound these notches anteriorly".

Corresponding to the anatomy outlined above, oblique roentgenograms of the cervical spine show that the anteromedial borders of the intervertebral foramina are formed, in the main, by the lateral lips of the superior surfaces of the third to the seventh cervical

vertebral bodies, by the bevelled lateral margins of the bodies above, and by only a narrow seam of the thin intervertebral disc. Lateral roentgenograms show the lateral lips posteriorly touching the dorsal surfaces of the bodies or protruding slightly beyond. The upper surface of the first thoracic vertebra also shows lateral lipping, in this respect resembling the body of a cervical vertebra. In 1858 von Luschka pointed out that in the cervical spine the discs do not extend as far laterally as the bodies themselves, and that the lateral lips of the cervical vertebral bodies form articulations with a small facet of the next higher body. He counted these articulations in the category of hemiarthroses (half joints), calling them *hemiarthroses intervertebrales laterales,* while Trolard created for them the term uncovertebral joints.

Lange and Krogdahl and Torgersen stressed the existence of some sort of lateral articulations between the vertebral bodies of the cervical spine, and they described joint-like gaps as a normal occurrence in the lateral portions of the intervertebral discs. They described the lining of the gaps as a fibrous capsule-like lateral membrane. This fibrous membrane and the lateral articulations between the individual bodies of the cervical spine could not be verified, either by Rathcke or Güntz, and the latter doubts their existence.

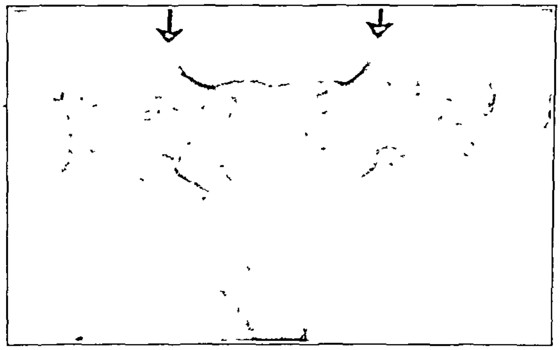

FIG. 1

Anteroposterior roentgenogram of a typical cervical vertebra, showing the lipping on the lateral upper surface.

Krogdahl and Torgersen stress the need of distinguishing between the lateral joint-like gaps and the more medially situated, irregularly outlined, inconstant gaps, which they think may be artificially produced, where no signs of degeneration are noticeable. They express doubt as to whether one is entitled to consider these lateral junctions as true articulations, since they lack a number of important features characteristic of joints. In any event, the existence of such lateral articulations between individual cervical bodies has not been demonstrated. The lateral portions of the intervertebral discs between the central and lower cervical vertebrae almost invariably contain gaps and tears, not to be mistaken for articular cavities, but not clearly set off against the rest of the disc. The system of cavities existing within the nucleus pulposus normally may be considerable. The gaps may extend from there into the annulus fibrosus or beyond, particularly posteriorly, where they may develop into the so-called recessus posterior of the cavity of the nucleus pulposus. However, it should be remembered that the tissue of the disc has no regenerative capacity. If tissue in the disc is destroyed, owing to excessive functional strain, it is not replaced as it would be in the bones, and functional adjustment does not take place. Therefore, tears and other marks of destruction occur rather frequently in the discs.

Only with these special features, characteristic of intervertebral discs, in mind, may we attempt to understand the etiology of the uncovertebral osteophytes and osteochondrosis of the cervical spine.

UNCOVERTEBRAL OSTEOPHYTES

The uncovertebral osteophytes occur at the lateral, and especially the posterolateral, lips of the superior surfaces of the third to the seventh cervical bodies. It is suggested that these osteophytes may be factors in the creation of the syndrome characterized by neuralgic symptoms of the arms, neck, and back of the head. The laterally lipped upper surface of the first thoracic vertebral body also develops exostoses, which are easily identified in the anteroposterior roentgenogram. Lange calls them spondylosis deformans of

the *hemiarthroses intervertebrales*, Krogdahl and Torgersen speak of *arthrosis deformans uncovertebralis*, and Lange and Güntz refer to them as spondylotic exostoses. These osteophytes are found at some distance laterally and posteriorly from the anterior longitudinal ligament, an important element in their etiology. Therefore, uncovertebral osteophytes cannot be considered secondary to spondylosis deformans, although they may appear in vertebra changed by spondylosis or arthrosis deformans [degenerative arthritis]. Giraud and Krogdahl and Torgersen maintain an etiological relationship between the bony proliferations of the uncinate processes and arthrosis deformans. As there exist no joints in connection with the uncinate processes, uncovertebral osteophytes cannot possibly be produced by the same mechanism as arthrosis deformans [degenerative arthritis]. The uncovertebral osteophytes and marginal proliferations at the lower surface of the upper vertebral body appear as a consequence of osteochondrosis of the spine [degeneration of the disc].

OSTEOCHONDROSIS OF THE CERVICAL SPINE

Osteochondrosis may run its course without causing symptoms. As we are dealing with a degenerative process, the sedimentation rate of erythrocytes remains normal. While spondylosis deformans is primarily a degenerative affection of the annulus fibrosus of the aging disc (without or with only slight involvement of the nucleus pulposus), osteochondrosis is characterized by a degenerative, destructive process of the intervertebral disc as a whole, which includes loss of structure and destruction of the nucleus pulposus. Through the effects of age and continuous stress, the intervertebral discs pass through stages of fibrillation, dehydration, and fissuring; the adjacent vertebral bodies undergo subchondral osteosclerosis, marginal proliferation, and decrease in height. The destruction of the discs may assume such proportions that the bodies rub against each other. One of the sequelae of the degeneration of discs as a whole is the marginal bony proliferation of the lateral lips of the cervical bodies and of the lower surface of the body above.

CLINICAL ASPECTS

Forty cases are briefly reviewed. Except for three, all patients were over forty-five years of age. Twenty-two were men. Special emphasis was not given to persons engaged in laborious occupations, nor to those whose work involved any special movements of the cervical spine, such as watchmakers or precision-machine operators. Most of the patients complained of boring brachial pain, radiating down one or both arms, with a tingling sensation in the fingers, and pain in the shoulders and the back of the head. Sensitivity to cold and pain was particularly marked at night, so that sleep was often disturbed. Many patients complained of dizziness, headache, earache, dysphonia, and transitory swelling of one hand or forearm. Muscle strength was impaired, but distinct sensory symptoms were rarely noted. One or both occipital nerves were invariably sensitive to pressure, as were the cervical and brachial plexus and the trapezius on one or both sides.

ROENTGENOGRAPHIC FINDINGS

The most striking effects were observed in the roentgenograms. The anteroposterior view showed reduced height of one or several of the vertebral bodies from the fourth to the seventh cervical inclusive, as well as of the corresponding intervertebral spaces. Also evident were atrophy, bony lipping of one or several uncovertebral osteophytes, and marginal proliferations at the lower surface of the body above the one affected.

An oblique roentgenogram showed uncovertebral osteophytes and marginal proliferations of the inferior surface of the vertebral body above. One or more of the intervertebral foramina were often narrowed. There were occasional exostoses in the foramina between the seventh cervical and the first thoracic vertebrae. Uncovertebral osteophytes were found with particular frequency in the sixth cervical vertebra.

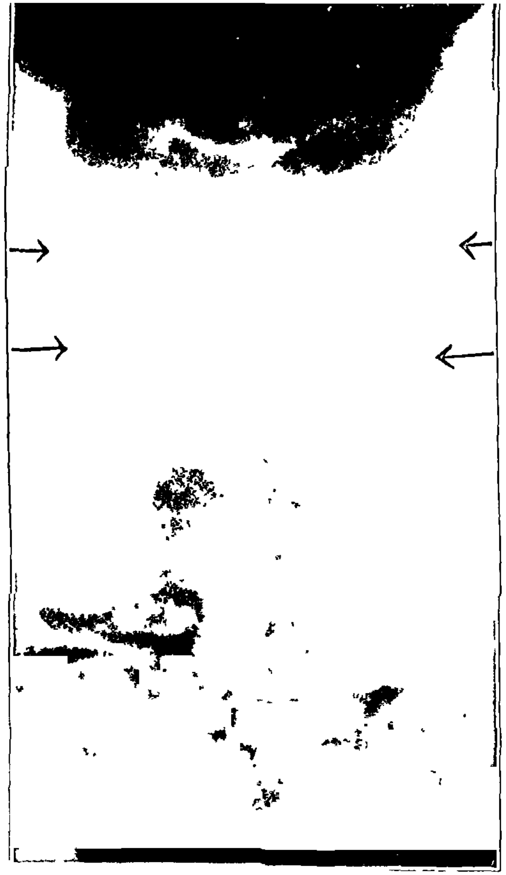

FIG. 2-A

E. S. Anteroposterior roentgenogram of a patient sixty-one years old, showing uncovertebral osteophytes of the fifth and sixth cervical vertebral bodies and marginal proliferations of the inferior surface of the fifth cervical body.

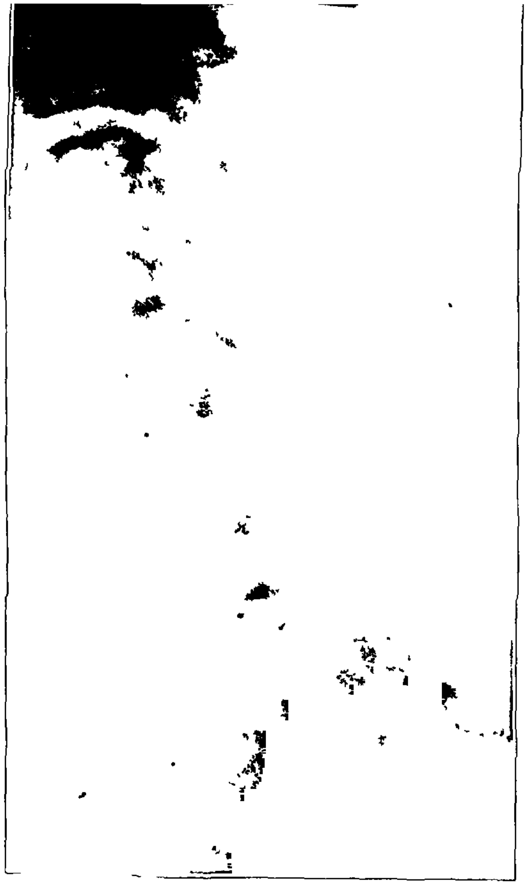

FIG. 2-B

Lateral roentgenogram of the same patient, showing spondylotic osteophytes of the anterior edges of the fifth, sixth, and seventh cervical vertebral bodies, and narrowing of intervertebral joints.

FIG. 2-C

Oblique roentgenogram of the same patient, showing uncovertebral osteophytes projecting into the intervertebral foramina between the sixth and seventh cervical vertebrae and between *the* seventh cervical and the first thoracic vertebrae.

In the lateral view, spondylotic osteophytes were seen at the anterior edges of the bodies of several of the cervical vertebrae. Posterolateral uncovertebral osteophytes occasionally projected slightly beyond the bodies, appearing to be intraspinal, but actually were within the foramina.

CASE REPORT

E. S., a merchant, sixty-one years old, reported that five years before he had suffered for some months from neuritis of both arms. During the past four weeks there had been weakness and numbness of the left arm, and a tingling sensation down to the finger tips. The symptoms were more pronounced at night and were markedly influenced by cold. The cervical spine was tender to pressure. Active and passive movements in the shoulder joint were normal. The left brachial plexus was sensitive to pressure. No sensory or motor disturbances of any significance were noted in the arms, apart from considerable awkwardness in performing more delicate movements. On the left, the trapezius was tender. The sedimentation rate was normal.

The anteroposterior roentgenogram (Fig. 2-A) showed bony atrophy of the bodies of the cervical vertebrae, particularly of the fifth. Lumpy uncovertebral osteophytes were seen on both sides of the sixth cervical body, and marginal proliferations at the lower surface of the fifth. There was thickening of the uncovertebral processes on both sides of the fifth cervical body.

The left lateral roentgenogram (Fig. 2-B) showed loss of the normal curvature of the cervical spine. Spondylotic osteophytes were seen at the anterior edges of the fifth, sixth, and seventh cervical vertebrae. There was narrowing of the posterior articulations.

The left oblique view (Fig. 2-C) showed osteophytes at the lateral lips of the seventh cervical and first thoracic vertebral bodies, protruding into the intervertebral foramina between the sixth and seventh cervical, and between the seventh cervical and first thoracic vertebrae.

The diagnosis was spondylosis and arthrosis deformans with uncovertebral osteophytes.

DISCUSSION

In the case illustrated the presence of uncovertebral osteophytes and exostoses at the lower bevelled surfaces of the vertebral body suggests a primarily degenerative lesion of the underlying narrow intervertebral disc. Krogdahl and Torgersen reported occurrence of rather large exostoses in conjunction with osteochondrosis [degeneration of the disc], exclusively "at the edges of the uncovertebral joints". From this they conclude that the pathogenesis of these exostoses must necessarily be different from that established for osteophytes arising on the basis of marginal bony proliferation at ligament attachments. With this the author agrees. However, it should be borne in mind that arthrotic exostoses of the posterior articulations may be co-existent with osteophyte formation on the basis of osteochondrosis.

Characteristic of osteochondrosis of the cervical spine is the abnormal posture and reduced mobility of that part. Resulting abnormal mechanical conditions reduce the normal lordosis, and may occasionally lead to kyphosis. The majority of symptoms are caused by the excessive strain imposed on muscles and ligaments. Narrowing of the intervertebral foramina is caused by ingrowth of the uncovertebral osteophytes, which may result in pressure on vessels and nerve roots at this site. These spicules are seen in oblique roentgenograms. The writer agrees with Giraudi that uncovertebral exostoses are more frequently the cause of nerve symptoms than are exostoses arising from the small posterior articulations as a result of arthrosis deformans.

According to Krogdahl and Torgersen, the more anteriorly situated osteophytes of the uncinate processes may project into the canal of the vertebral artery, affecting the contained sympathetic fibers and the artery. These uncovertebral osteophytes, appearing in anteroposterior roentgenograms, are the cause of the cervical posterior sympathetic syndrome of Barré, consisting of headache, pressure behind the eyes, dizziness, tinnitus, earache, and dysphonia. Damage to the spinal cord from posterolateral uncovertebral osteophytes has not been observed.

THERAPY

In the treatment of osteochondrosis, much benefit is derived from the use of moist

heat or simple cotton bandages applied on the cervical spine. Antineuralgics or other analgesics are indispensable. The patient should be advised to rest his neck on a soft roll at night. In severe cases, injections of large doses of procaine solution into the affected plexus are occasionally successful. However, it is true that 10 per cent. of our cases did not yield to therapeutic measures. One patient, with considerable narrowing of several intervertebral foramina and with several exostoses probably projecting into the right canal of the vertebral artery, did not show improvement even after two years of treatment.

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THE RESULTS OF EPIPHYSEODESIS AND FEMORAL SHORTENING IN RELATION TO EQUALIZATION OF LIMB LENGTH*†

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FOLLOW-UP STUDIES

Many methods have been proposed for the equalization of length of the lower extremities. Most of these were of little more than theoretical value, because results were either too slight or too uncertain. Others presented complications which have made them unpopular. Into this group fall bone-lengthening operations, and possibly growth arrest by irradiation. Two methods have been more generally accepted, because of their relative simplicity and apparent effectiveness. They are (1) epiphyseodesis (epiphyseodiaphysial fusion) and (2) bone shortening,—principally femoral shortening.

It is our purpose in this study to evaluate the results of these two operations as observed in a series of cases treated at the Hospital for Special Surgery.

I. Epiphyseodesis

The technique of epiphyseodiaphysial arrest used in this series is that described by Phemister in 1933, with the exception that in most cases we tried to curette more of the epiphyseal cartilage. In addition, the remaining portion of the epiphyseal plate was thoroughly cauterized with electrocautery. Weight-bearing without mechanical aids was generally allowed at the end of three weeks. Immobilization in plaster-of-Paris was employed in only three of the four more recent cases.

Method of Determining Age and Extent of Proposed Epiphyseal Fusion

The proper timing of the operation with respect to the patient's age, and the estimation of the expected growth of the two limbs, and of the discrepancy that will result, constitute the most difficult and probably the most inaccurate part of the whole procedure. The method used here has been previously described by two of us [4]. It is based on the estimated percentage of limb length that is contributed by the growth from the upper tibial epiphysis (25 to 30 per cent.) and of the lower femoral epiphysis (30 to 35 per cent.). The formula for calculation is:

$$\frac{\textit{Expected Discrepancy}}{\textit{Expected Growth}} \textit{ equals the percentage of growth to be eliminated.}$$

The estimation of expected growth is usually based upon the measurement of the father's or the mother's limb length, depending upon the child's sex. This is not an infallible guide, and it is generally true that today most children are taller than their parents. If we err in our predictions, it is likely to be because we underestimate rather than overestimate the amount. We also take into consideration the height of the child in relation to the average height of children of the same age, and any information we may be able to obtain of the parents' height at the same age.

For example, let us take a boy of twelve years of age with a postpoliomyelitic involvement of one leg, but able to get about actively without a brace. The limb length on the normal side is thirty inches and on the involved side twenty-eight inches. The boy is of

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† This study was aided by a grant from The National Foundation for Infantile Paralysis, Inc.

average height for his age; his father's height is seventy inches and his limb length thirty-six inches. Our prediction of expected growth is six inches and our formula is as follows:

$$\frac{(\textit{Expected Discrepancy})\ 2\ \textit{inches}}{(\textit{Expected Growth})\quad 6\ \textit{inches}}\ \textit{equals 33 per cent.}$$

In other words, we should eliminate 33 per cent. of the expected growth, which corresponds approximately to what we may expect from the lower femoral epiphysis, and we would perform an epiphyseodiaphysial fusion. If we fused the upper tibial epiphysis, we would obtain too little correction, and if we fused both the lower femoral and upper tibial epiphyses, we would obtain too much correction (55 to 65 per cent.).

This method of prediction is not entirely accurate; perhaps no method is. We have had no experience with the method of Abbott and Gill. As will be seen, there are many individual variations in bone growth, and factors of sex and age of attaining sexual maturity may also be important.

Method of Measurement

The measurements of limb length upon which the study is based were made by use of a tape, measuring from the anterior superior spine of the ilium to the medial malleolus, checked by trial of different elevations of known height under the short limb in the standing position. While we realize the variation of measurements by different surgeons making use of the same bony landmarks, we believe that there will be little variation in the net difference between the length of the legs, which is of chief importance. We experimented with roentgenographic measurements of both limbs, made on double-length

TABLE I

CONDITIONS CAUSING DISCREPANCY IN LEG LENGTH

Condition	No. of Cases	Condition	No. of Cases
Poliomyelitis	68	Congenital deformities	2
Epiphyseal injury	1	Congenital coxa vara	2
Compound fracture	1	Congenital pseudarthrosis	3
Tuberculosis of hip	1	Congenital dislocation of hip	2
Osteomyelitis	2	Congenital shortening	1
Hemangioma	1	Spina bifida	1
Osteitis fibrosa cystica	2	Spastic hemiplegia	1
Liposarcoma	1		
		Total	89

TABLE II

ANALYSIS OF OPERATIONS

Etiology	No of Cases	Type of Epiphyseodesis			Total Operations
		Femoral	Tibial, Fibular	All Epiphyses	
Poliomyelitis	68	24	40	15	79
Other etiology	21	5	8	11	24
Totals	89	29	48	26	103

TABLE III

CLINICAL EVALUATION

Results	Cases	Per cent.
Good results (discrepancy of 2 centimeters or less of anticipated gain)	40	49.4
Mediocre (some incomplete)	21	25.9
Poor (discrepancy of over 3 centimeters or gain not realized)	20	24.7
No clinical data	8	

films with a metal rule strapped to one thigh to serve as an index to the amount of magnification or diminution, but concluded that the margin of error was unimportant. In cases of pelvic asymmetry, even roentgenographic measurements may be inaccurate, and in such cases the best method is that of trying elevations of different height under the foot.

Review of Cases

From 1935 to January 1942, 103 epiphyseodesis operations were performed on eighty-nine patients at the Hospital for Special Surgery. In sixty-eight cases the etiological factor in the discrepancy of limb lengths was poliomyelitis. In twenty-one cases other etiological factors were responsible (Table I). (This latter group are hereafter referred to as non-paralytic cases.) It will be noted in Table II that in twenty-nine cases the femoral, and in forty-eight cases the upper tibial and fibular epiphyses alone were fused. In twenty-six cases all the epiphyses about the knee were fused in one stage, representing 22 per cent. of the poliomyelitic cases and 52.4 per cent. of the non-paralytic cases. This difference indicates that the actual or expected discrepancy was generally greater in the latter group. In thirteen of the cases all epiphyses were closed, but in two operations at different times. In these cases there was generally uncertainty as to the expected discrepancy, and the second operation became necessary when the first proved inadequate. This occurred in ten instances in the poliomyelitic group, while it happened in only three cases in the non-paralytic group (Table II).

The age at time of operation ranged from six years to fifteen years; there being only one patient of six, none of seven, and seven of eight years of age. The largest groups were in the ninth, tenth, and eleventh years.

The period of follow-up extends from one to eight years, averaging three and two-tenths years.

EVALUATION OF RESULTS

Evaluation of epiphyseodesis in this series was open to the following sources of error:

1. Lengths of extremities determined by clinical measurement were used as a check on the operation, and of necessity were frequently made by different clinicians with variable results. Roentgenographic measurement was used in some cases, but this seemed to offer no real advantage.

2. In many cases the operation was performed to arrest or to retard an increasing discrepancy, rather than to gain true equalization of limb length. Follow-up measurements may show no correction of discrepancy, and yet the result may well be considered good. This is especially true in the non-paralytic series.

3. Occasionally operations were performed following epiphyseodesis for the purpose of increasing joint stability or correcting deformity, and these operations may have altered limb lengths, or affected the accuracy of mensuration to some extent.

There are two methods of evaluating the results. The first is to consider them from the standpoint of a final discrepancy of two centimeters or less, which can be easily cor-

TABLE IV

ANALYSIS OF RESULTS OF OPERATIONS

Results	Poliomyelitis	Other Etiology	Average Age, Female	Average Age, Male	All Epiphyses	Tibial and Fibular	Femoral	Totals
Good results (75 per cent correction or better)	15	3	10.2	10.8	8	7	3	18 (22.7 per cent)
Mediocre or incomplete (25 to 75 per cent correction)	24	8						32 (40.5 per cent)
Poor (25 per cent or less correction)	17	4	11	13.6	9	6	6	21 (26.5 per cent)
Deformity requiring operative correction	8							8 (10.1 per cent)
Slight deformity, no correction required	7							7
Total deformities								15 (16.8 per cent)
Not sufficient data or complicated by other factors								10

rected by a small shoe elevation. In general, so slight a discrepancy may be considered a good result. Included in this group are those cases in which the purpose of surgery was merely to prevent an increase in discrepancy, when the anticipated result was obtained. This then is a *clinical evaluation.*

The second method is to use the percentage of discrepancy attained as a basis of evaluation. This permits a mathematical estimation of the perfection of the operation and of the accuracy of the method of prediction, but does not necessarily reflect the actual clinical result. In this method we have arbitrarily considered a correction of discrepancy of 75 per cent. or better as a good result, while 25 per cent. or lower is graded as poor. Corrections which fall between 25 per cent and 75 per cent. are considered mediocre, or in some cases incomplete results.

Though not precisely true, we have considered growth of the extremities complete at fourteen years in females and at sixteen in males. According to this standard, eighteen of the eighty-nine patients were still growing at the time of evaluation, and the results may be considered still incomplete.

FIG. 1-A FIG. 1-B

Case A.Y. Illustrating deformity of medial condyle of tibia following epiphyseal arrest. Fig. 1-A November 6, 1939. Fig. 1-B March 1, 1943.

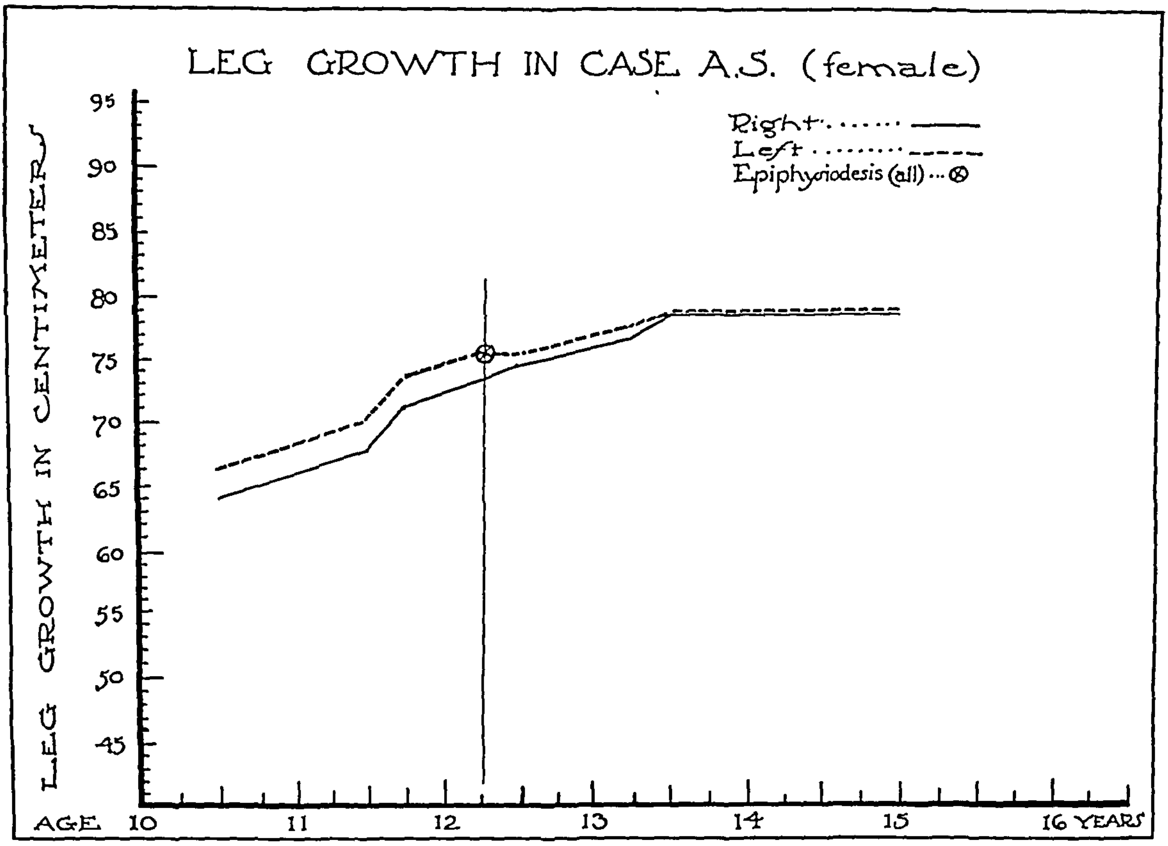

FIG. 2

Evaluation by First Method (Clinical impression)

Employing the first method—namely, a final discrepancy of two centimeters or less plus the cases in which an anticipated goal was attained—forty cases or approximately 50 per cent. came within the desired result. Ten were in the non-paralytic group. By sexes, the group was evenly divided. Of the thirty poliomyelitis cases here included, only one had so slight a discrepancy as two centimeters preoperatively. In eight cases observations were insufficient. Percentages in this method are, therefore, based on a total of eighty-one cases (Table III). While considering clinical results, it would be wise to discuss the deformities of growth resulting from operation and requiring operative correction.

Deformities resulting from unequal arrest of growth of all parts of the epiphysis constitute a serious hazard, especially in elective surgery (Fig. 1). The deformities usually developed within one year following operation. Those so severe as to warrant further corrective surgery were classed as poor clinical results, even though the final result may have been good. In eight cases, or 10.1 per cent. of the series, the deformities were severe enough to require corrective operations. In another seven cases, deformities were noted, but they were not severe enough to require operative correction, and did not affect the final result. They do, however, emphasize the risk of this complication. Therefore, a total of 16.8 per cent. of this group of patients showed some deformity resulting from epiphyseodesis. Of these, seven patients showed valgus; and six patients, varus deformities. In one case the type of deformity was not recorded. In the remaining case, a severe double deformity developed, with varus of the lower femoral and valgus of the upper tibial epiphyses.

We believe that most of these deformities of growth resulted from faulty operative technique, especially in the preparation and placing of the bone grafts. The facts that most of these cases did not have plaster-of-Paris immobilization, and that early weight-bearing was permitted may have been contributory factors. In only one case was excessive correction obtained. This patient was a boy with poliomyelitis, who had had the

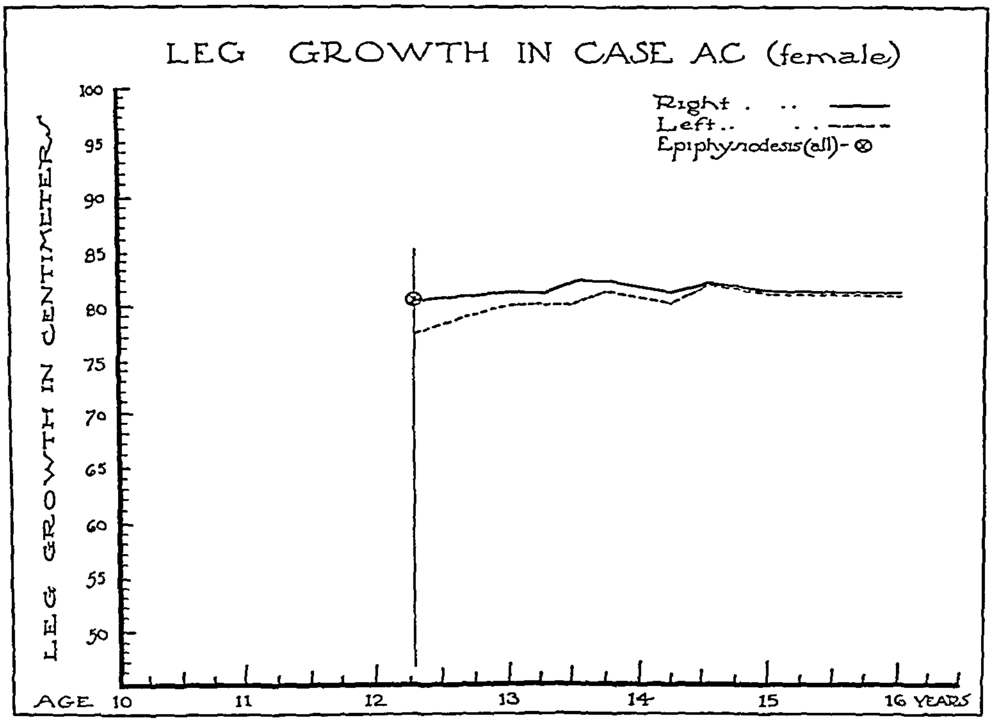

FIG. 3

upper tibial and fibular epiphyses fused at the age of eleven years when the discrepancy was 1.5 centimeters. At the age of fifteen years the length of the short leg exceeded that of the leg operated upon by one centimeter, but this difference was well within the range of a good result.

Evaluation by Second Method (Percentage of correction of discrepancy attained)

This stricter method, as was said before, reflects more the accuracy of the method of prediction than the success of the result from a clinical standpoint. Eighteen cases, or 22.7 per cent. of the series, were rated as good results, — that is, they obtained a correction of 75 per cent. or better of their preoperative discrepancy (Table IV).

Insufficient correction of discrepancy as seen in Table IV was obtained in twenty-one, or 26.5 per cent., of the cases Of this group, sixteen, or 76 per cent., were female, and five were male.

It was noted in most of this group of cases that either the operation was done too late, or too little was done. Epiphyseodesis after eleven years in the female and after twelve to twelve and a half years in the male is of questionable value. In this group of poor results, seven females were over eleven years; three males were over twelve years. Of these ten cases, total epiphyseodesis was done in seven.

While this rule applies for the great majority of cases, there are marked individual variations in both directions This is illustrated by the following cases:

CASE 1. A. S, a girl, twelve years old had had poliomyelitis All epiphyses were closed at twelve years and four months. When thirteen years, seven months old she had gained 2.5 centimeters and limb lengths were equal.

Little or no correction should have been expected at this age, but equalization was obtained (Fig. 2).

CASE 2. A. C., a girl of twelve years had suffered from osteitis fibrosa cystica She had all epiphyses closed at twelve years, but within two years she had completely overcome a discrepancy of 3.1 centimeters (Fig. 3).

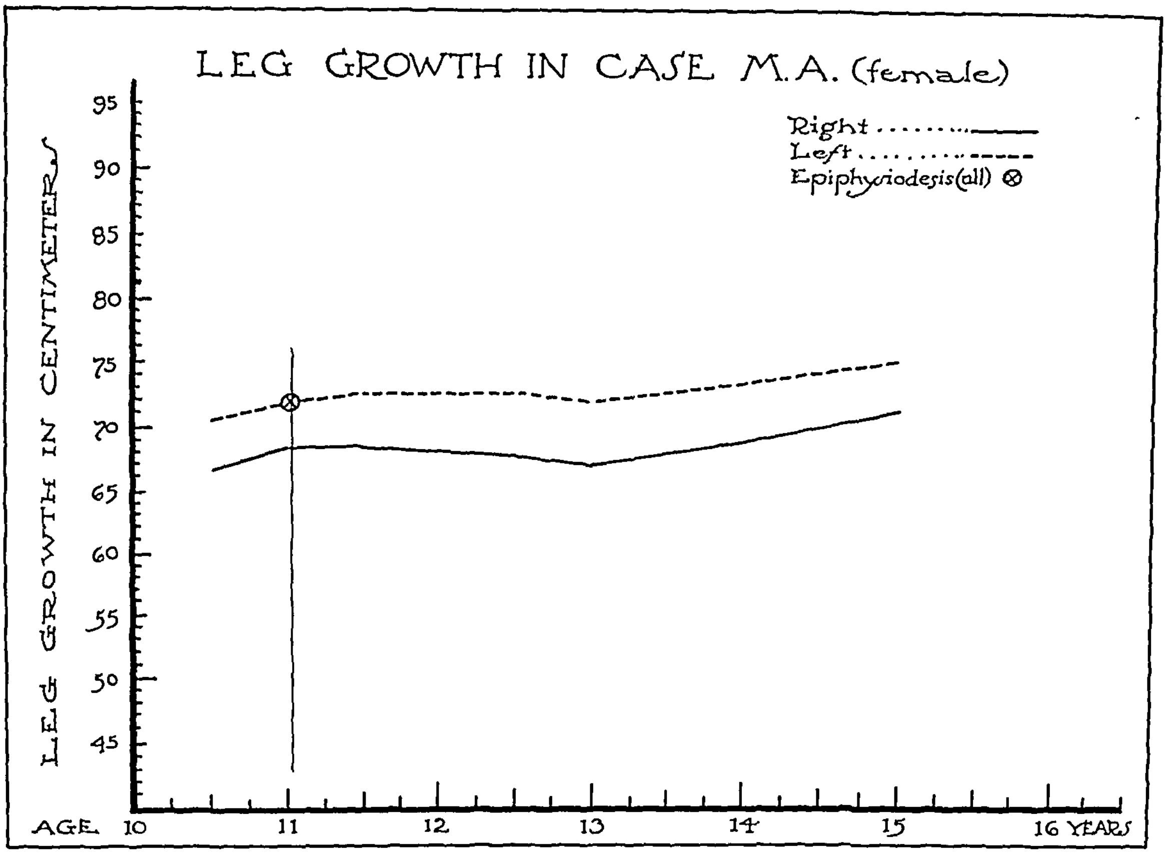

FIG. 4

These two cases represent marked variations from the average in a desirable direction. However, the opposite more frequently seemed to occur.

CASE 3. M. A. was a poliomyelitic case. The girl had all epiphyses about the knee closed at eleven

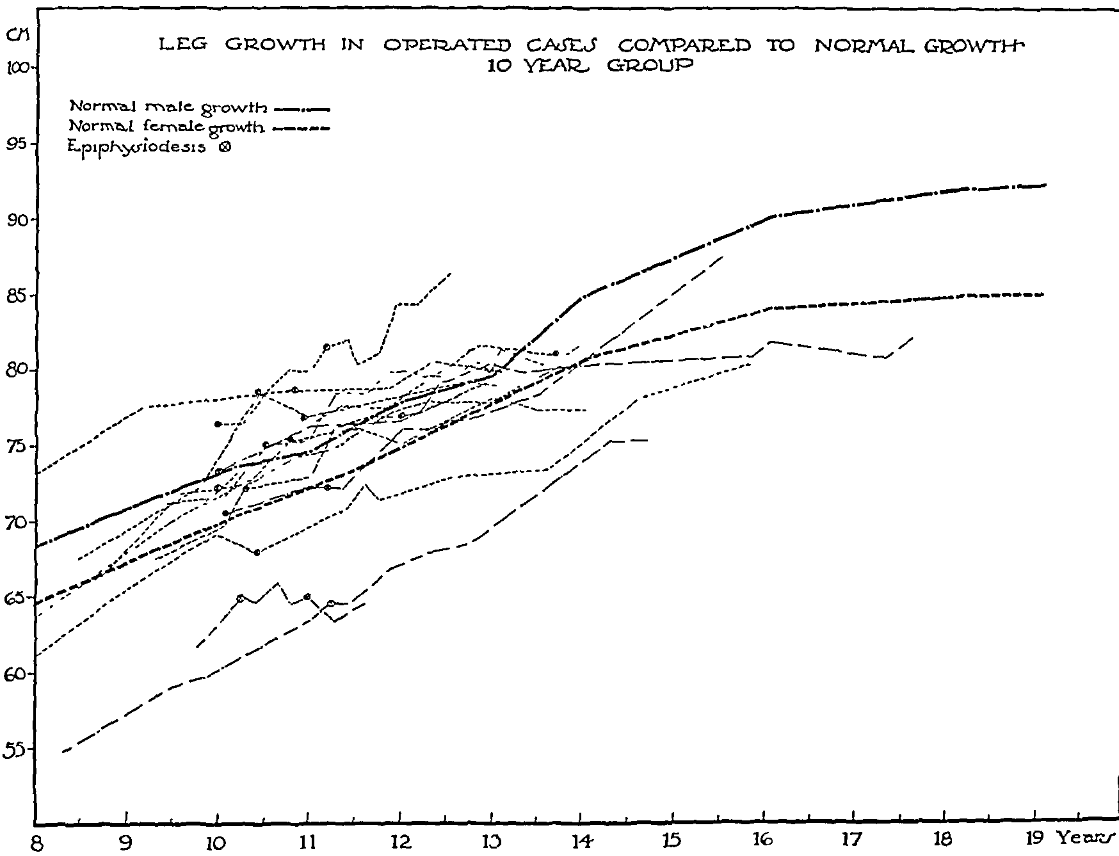

FIG. 5 (Table V)

years. At fourteen her discrepancy remained the same, and her limb lengths had not increased perceptibly. She was short and of a Mediterranean race (Fig. 4).

There were a number in the group who conformed to this general picture, and in whom failure was encountered. This would lead to the conclusion that race might be an important factor. An analysis of the poor results, however, revealed that the group was almost evenly divided between Nordic and Mediterranean types. However, the female patients mentioned above were of a physical type that attains secondary sex characteristics early, and it was our personal observation that usually little growth could be expected in these individuals. These cases, then, together with others previously mentioned in which good results were obtained, serve to illustrate variations in growth, which make the usual methods of prediction inadequate. The extent of these variations can best be illustrated by the following analyses:

Group I

Females, twelve or thirteen years of age at operation.
(Ten were poliomyelitic cases and six were non-paralytic.)
Five made no gain.
Four gained approximately 25 per cent.
Two gained approximately 50 per cent.
Two gained approximately 100 per cent.
In three cases, no follow-up data were available.

Group II

Males, thirteen or fourteen years of age at operation.
(Seven were poliomyelitic cases and four were non-paralytic.)
Two made no gain.
Two gained approximately 25 per cent.
Four gained approximately 50 per cent.
One gained approximately 100 per cent. (lower femoral).
In two cases no follow-up data were available.

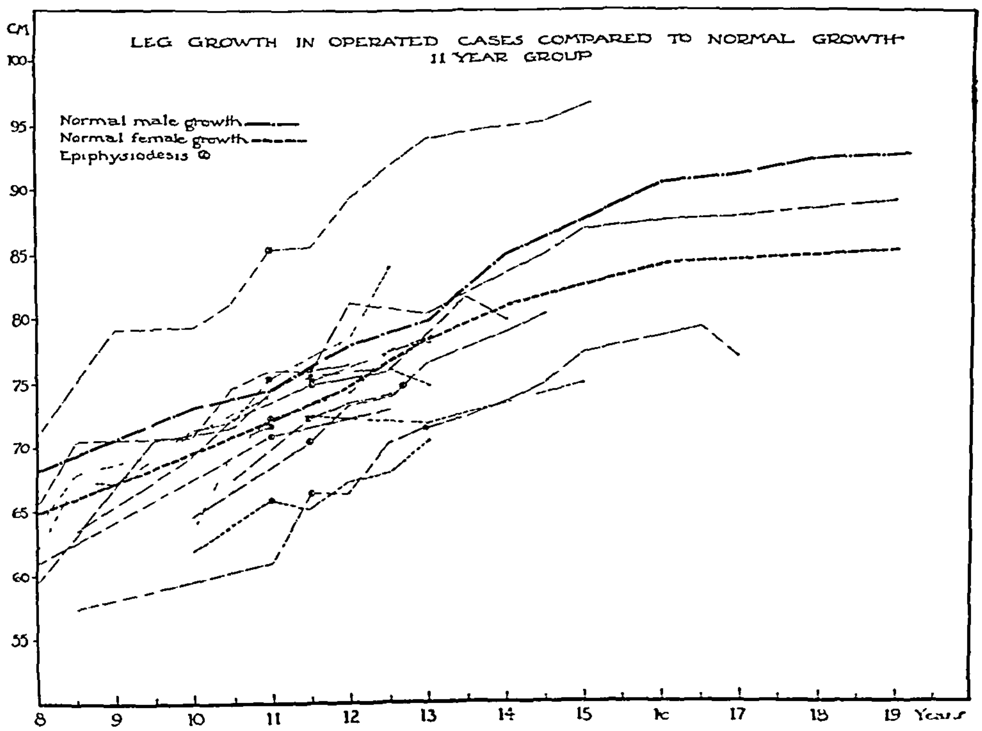

Fig. 6 (Table VI)

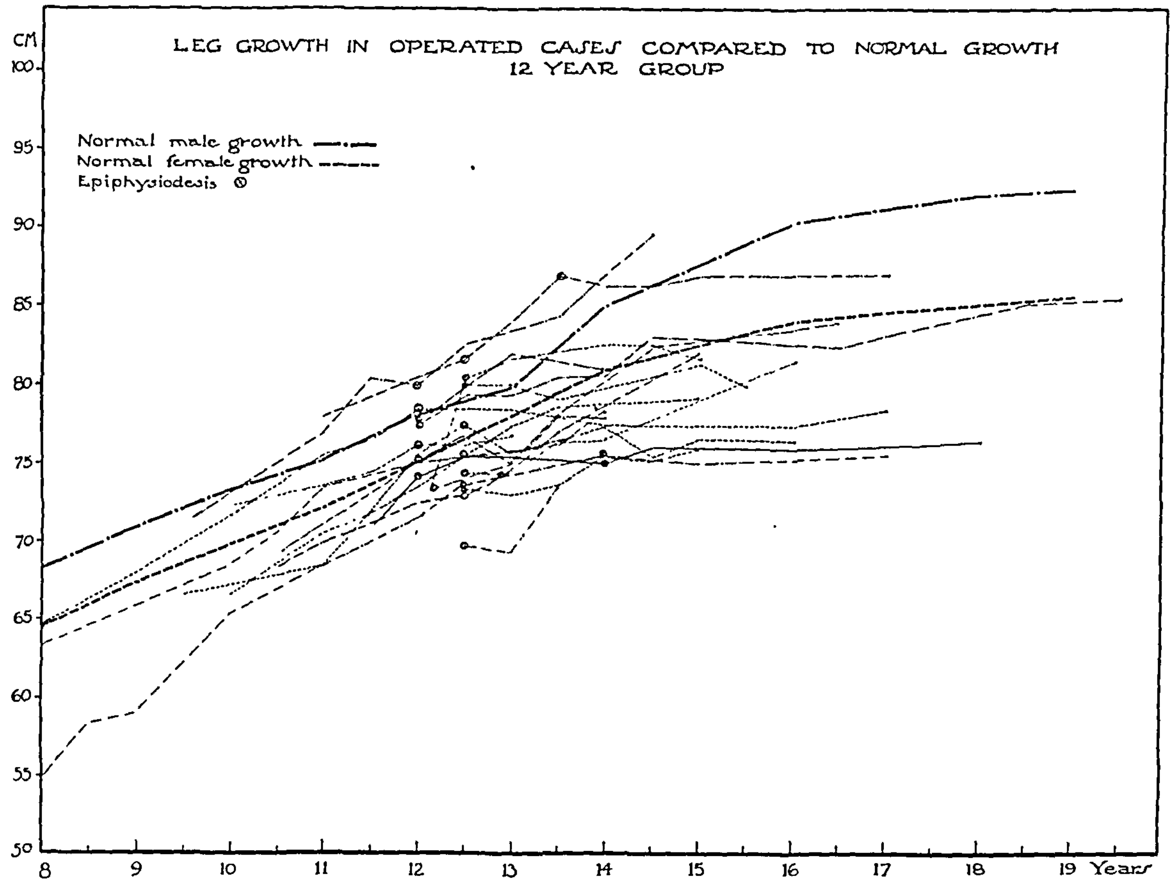

FIG. 7 (Table VII)

Of these cases in Group II, the two that showed no gain had all epiphyses closed; while in the one perfect case only the lower femoral epiphysis was operated upon.

One of the most interesting cases in the series was the following:

CASE 4. E. B., a girl, eight years old, was first seen in the Out-Patient Department on August 15, 1934, with an extensive deep hemangioma of the left leg. She was referred to another hospital for treatment by

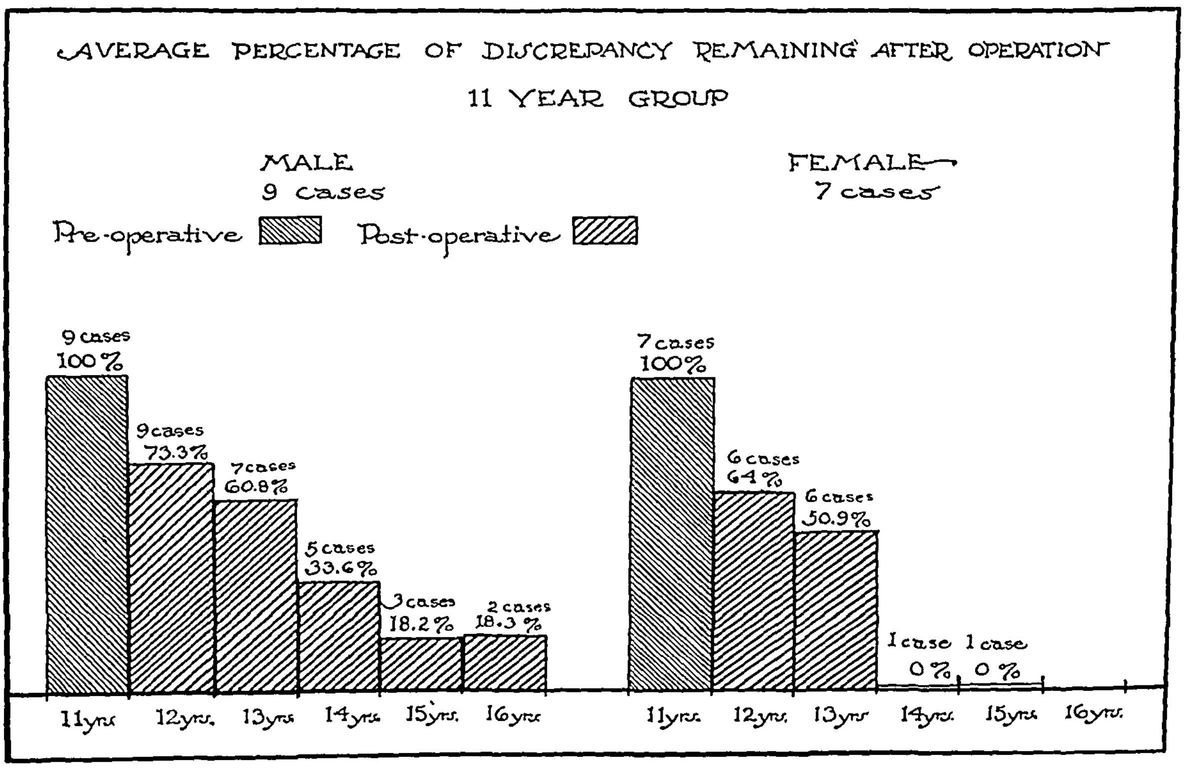

FIG. 8 (Table VIII)

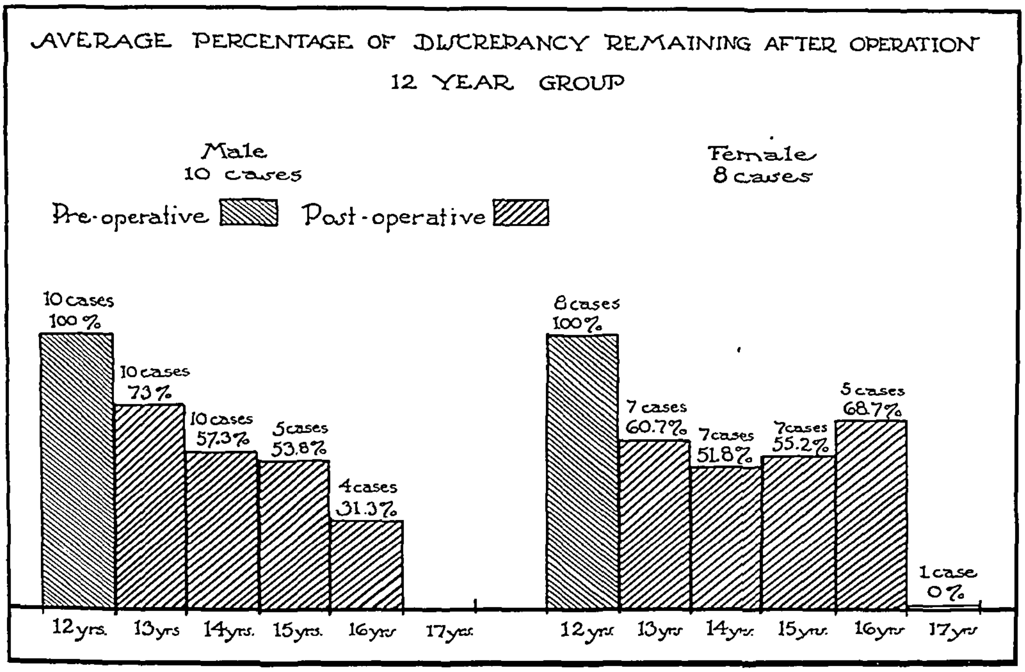

FIG. 9 (Table IX)

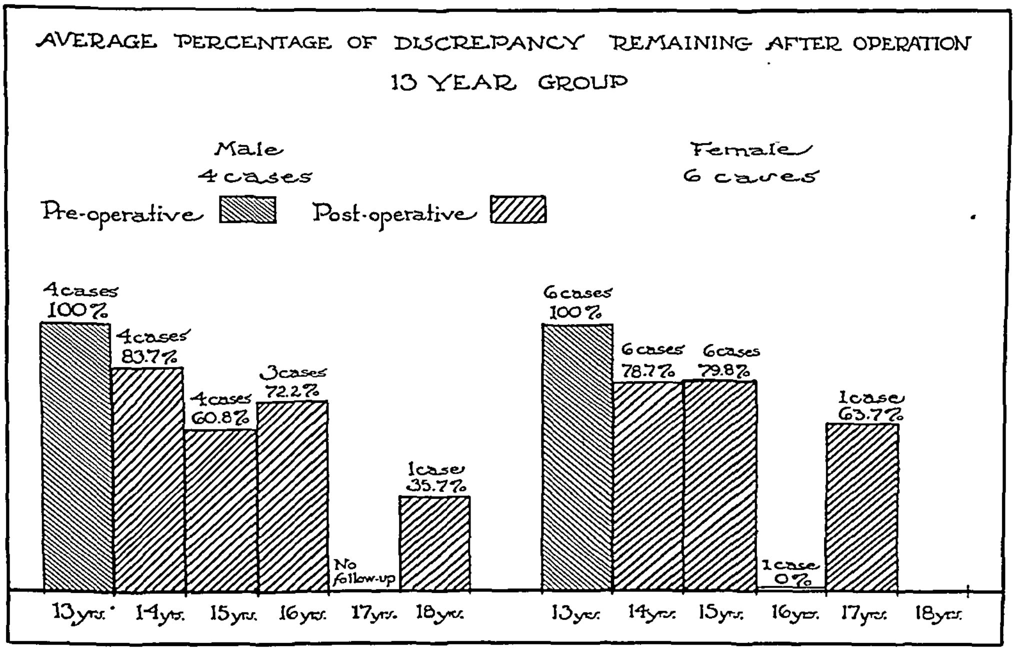

FIG. 10 (Table X)

irradiation. The recorded limb lengths were: right, 65.2 centimeters (24.4 inches); left, 67.5 centimeters (27 inches). She was given x-ray irradiation to all the epiphyses of the left tibia as this was the area of lengthening. Treatments were carried out through 1935 and 1936. In 1937 both limbs were recorded as equal in length at 76.5 centimeters (30.6 inches). The child was then eleven. In January 1939, it was noted that the length of the right leg exceeded that of the left by 2 centimeters. It was found that in the two previous years the patient had grown 9.5 centimeters on the right and only 7.5 centimeters on the left. Even though the patient was then thirteen years old, on April 12, 1939, a total epiphyseodesis was done on the right knee. The following measurements recorded on September 9, 1940, show that a good result was obtained:

Preoperative length—Right: 84 centimeters (33.6 inches); Left: 81.5 centimeters (32.6 inches).

Postoperative length—Right: 85 centimeters (34 inches); Left: 84.2 centimeters (33.7 inches).

II. Femoral Shortening

Since January 1938, nineteen shortening operations have been performed. Eightee of these were shortening of the femur; there was one shortening of tibia and fibula. I nine cases the cause of the discrepancy was poliomyelitis; in four cases osteomyeliti single cases were caused by fibrous dysplasia of bone, congenital shortening, slippe femoral capital epiphysis, tuberculosis of the hip, osteochondritis juvenilis, and congenit dislocation of the hip. Nine were males; ten females. Two of the males had had prev ous epiphyseodeses, one at thirteen years and six months, the other at fourteen year One female had had an epiphyseodesis at thirteen years without benefit.

The technique of the femoral operation was a long oblique osteotomy, done in ever case through Henry's anterior incision, with overlapping of the bone ends (Fig. 11 In the first case (D. E.) internal fixation was obtained by Steinmann pins transfixing th fragments, and kangaroo tendon. In all othe cases, internal fixation was secured by the use c several vitallium screws fastening the fragment together. External fixation, usually a plaste spica, was used in all cases for eight week Weight-bearing was generally permitted a twelve weeks.

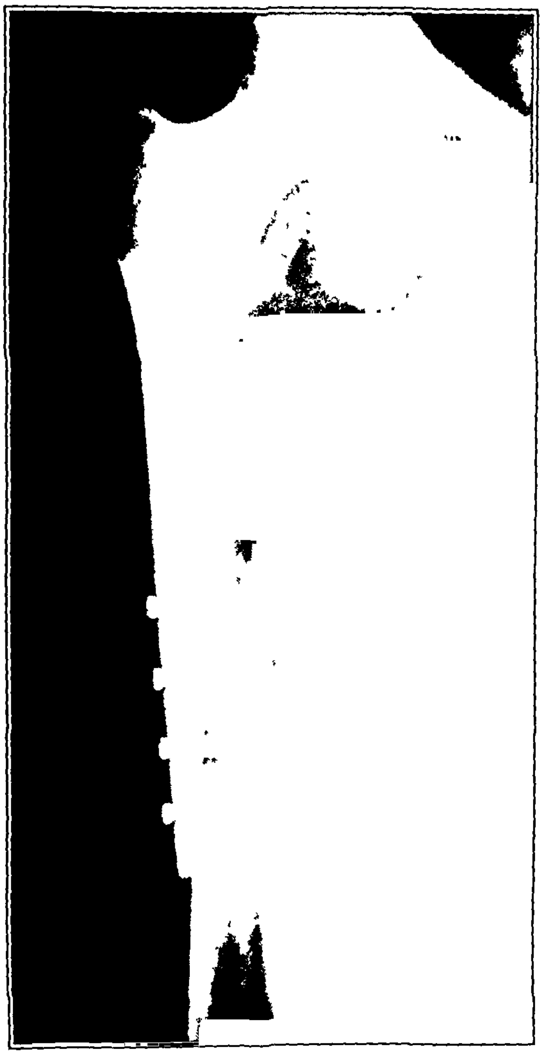

Fig. 11

Case R.C., July 1, 1942.

The age range at time of operation wa thirteen and a half years to forty-two years The follow-up period was from six years t twelve weeks.

The average correction obtained at operatio was 4.7 centimeters (1⅞ inches). The greates correction obtained was 5.7 centimeters (2¼ inches); the least 3.5 centimeters (1⅜ inches).

There were no non-unions or malunions There were complications in three cases (15.7 per cent.), but in all cases the final result was satisfactory.

1. C. L., female, nineteen and a half years old, had suffered from osteomyelitis of both hips, with resulting femoral shortening of 4.5 centimeters (1¾ inches). A postoperative wound infection with draining sinuses developed, and one year later it was necessary to remove vitallium screws and excise the sinus. This resulted in healing, and correction was maintained. This infection might have been anticipated, since both femora had been involved in the osteomyelitis.

2. B. C., male, fourteen years old, had probably suffered atypical fibrous dysplasia of bone, although the diagnosis was uncertain. Shortening of 5.7 centimeters (2¼ inches) of the left femur (the good limb) was performed on December 15, 1943. Postoperatively, the temperature rose to 101 degrees. There was continuous slight serous, non-purulent discharge from the wound. The cultures showed bacillus subtilis and staphylococcus albus. On February 5, 1944, the operative wound was opened widely, but abscess or deep infection was not found. The draining sinus continued until March 1, 1944. The boy was discharged well on March 10, 1944, and had no further trouble.

3. G. Mc., female, forty years old, had congenital dislocation of the right hip. Shortening of 5.7 centimeters (2¼ inches) of the left femur was done on July 6, 1943. The patient was unable to overcome the stiffness of the left knee after the plaster was removed. The pointed spike of the proximal fragment of the femur penetrated near to the suprapatellar pouch, and a calcified hematoma formed in this area, which required surgical excision on April 13, 1944. The patient recovered flexion to an angle of 70 degrees (Figs. 12-A, 12-B, and 12-C).

SUMMARY

I. *Epiphyseodesis:*

1. From the standpoint of the percentage of correction of the original discrepancy of limb length, only 20.7 per cent. of the results were classed as excellent (75 per cent. or more correction), and 23.1 per cent. of the results were poor (25 per cent. or less correction). This is chiefly a reflection on the timing of the operation and the selection of the epiphyses to be fused.

2. From the clinical standpoint, satisfactory results (final discrepancy of 2 centimeters or less) were obtained in 50 per cent. of the cases.

3. While, on the basis of our results, it is generally a mistake to perform epiphyseodesis for the correction of shortening in a female after the age of eleven years, and in a male after twelve and a half years, there were cases in our series which demonstrated that this is not always true. These exceptional cases tended to prove the inaccuracy of any method of predicting bone growth.

4. The development of bone deformities from unequal arrest of epiphyseal growth following operation was found in 20.7 per cent. of the cases. In eight cases, or 9.7 per cent., these deformities were too slight to affect the final result. They serve to emphasize the risk of the operation and the necessity for thorough fusion of the epiphyses.

II. *Femoral Shortening:*

1. Shortening of the femur by a simple, satisfactory technique was performed in nineteen cases, with ages ranging from thirteen and a half to forty-two years.

Fig. 12-A
Case G. Mc.: September 1, 1943.

Fig. 12-B
February 7, 1944.

Fig. 12-C
February 7, 1944.

2. The average correction obtained in this group was 4.7 centimeters (1⅞ inches). There were no instances of delayed union, malunion, or non-union.

3. Complications occurred in three cases. Two patients had postoperative infec tions, one transient and the other requiring secondary surgery. Both cleared up wit final good results. The third was a localized calcifying hematoma, causing limitation c knee flexion. A good result was obtained, following excision of the calcified mass.

CONCLUSIONS

1. The problem of equalization of limb lengths is a complicated one. No one pro cedure will provide the solution for all cases. Each case must be carefully studied, an surgery should not be undertaken without consideration of the risk involved. Epiphy seodesis, while apparently a simple and mild surgical undertaking, is irreversible an presents certain dangers which must be weighed in the balance. The possibility of sever growth deformity is the most important of these, and illustrates the need for meticulou and thorough technique during surgery itself. We also feel that, following operation, th healing epiphysis should be protected for a longer period than we have used.

2. In the selection of cases and of age for operation, the method used has provec satisfactory, but is nonetheless still inaccurate in some cases. The development of ac curate methods for exact prediction of bone age is needed. Race does not seem an im portant factor in growth prediction, but early sexual maturity, especially in girls, is a probable contra-indication to epiphyseodesis. Operation after the age of eleven in girl and twelve and a half in boys will avail but little in the average case. There were certair cases in this series, however, where splendid results were obtained later, usually in that group in which the development of secondary sex characteristics was delayed.

3. The operation is of particular value in young patients where the discrepancy is increasing rapidly, and a considerable difference in the length of the two extremities would be normally expected. In such cases, epiphyseodesis alone may suffice, or a femoral-shortening operation may be done later.

4. The use of epiphyseodesis is, of course, restricted to those still growing.

5. Femoral shortening is an exact procedure with a definitely predictable result. It is the only operation useful when growth has been completed. It presents a relatively simple surgical problem with a smaller percentage of complications than from epiphyseodesis. Its primary limitation is the maximum correction obtainable, about three inches.

6. The disadvantage of both epiphyseodesis and femoral shortening is the reduction of total height of the individual, which in persons of short stature is not desirable.

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Note: Discussion of this paper was included in the January issue of *The Journal* (See page 33).

CLOSED MANIPULATION FOR THE REDUCTION OF FRACTURES OF THE NECK OF THE RADIUS IN CHILDREN

BY RAPHAEL R. GOLDENBERG, M.D., F.A.C.S., PATERSON, NEW JERSEY

In the treatment of fractures of the neck of the radius in children, where the displacement is marked, many authorities[1,2,3,6,7] believe that only two methods are likely to give satisfactory results,—either excision of the capital fragment or open reduction. Sutro found that excision of the radial head may lead to overgrowth of the shaft of the radius. In the writer's experience, overgrowth of the radial shaft occurred in several instances and caused subsequent limitation of elbow motion.

In 1934, Patterson introduced a simple and effective manipulative technique for the reduction of fractures of the neck of the radius in children. The Patterson manipulation is performed with the elbow extended and the forearm supinated, an assistant exerting strong proximal traction on the arm. When the patient's left elbow is affected, the surgeon's right hand grasps the patient's left forearm just proximal to the wrist joint, and maintains strong distal traction on the supinated forearm. The surgeon's left hand is placed about the patient's medial humeral condyle, and firm lateral pressure is exerted. Then the forearm is slowly forced medially until the carrying angle is reversed, thus opening the lateral joint space. If the fragment is displaced posteriorly, the surgeon's left index and middle fingers are used to replace the fragment. If the fragment is displaced anteriorly, then the surgeon's left thumb is used for replacement of the radial head.

These fractures usually occur between the ages of five and thirteen. In each of the four cases to be described, the injury was caused by a fall on the outstretched hand. The force is transmitted along the radius and impacts the head against the capitellum. The head is held firmly by the annular ligament, and the proximal portion of the shaft is secured by the supinator and the biceps brachii muscles. The fracture occurs at the weak,

FIG. 1

Case 1. Fracture of the neck of the radius three and a half years after reduction

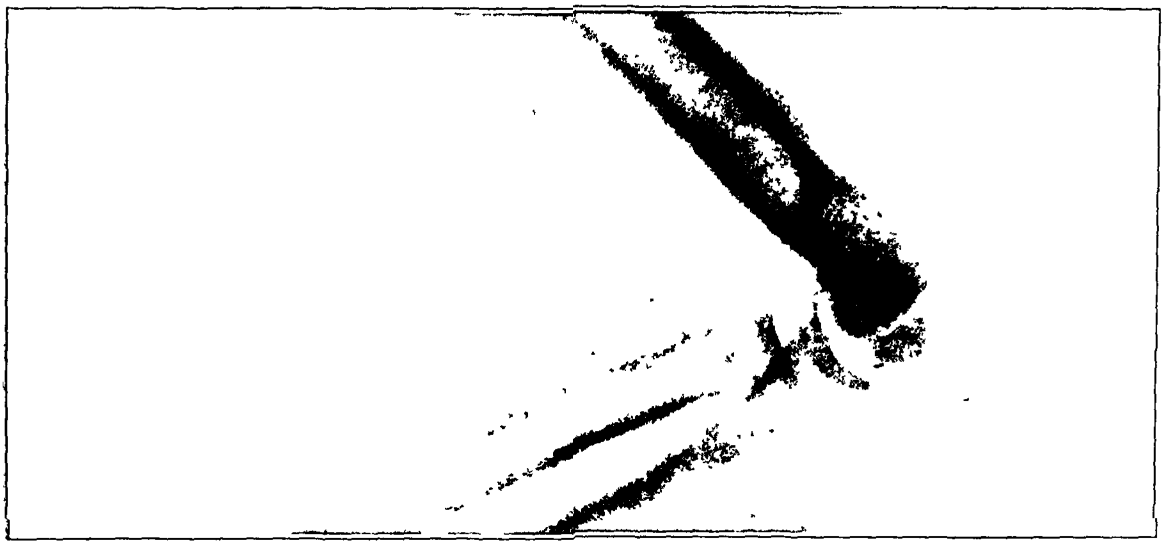

Fig. 2-B
Fracture of the neck of the radius after reduction.

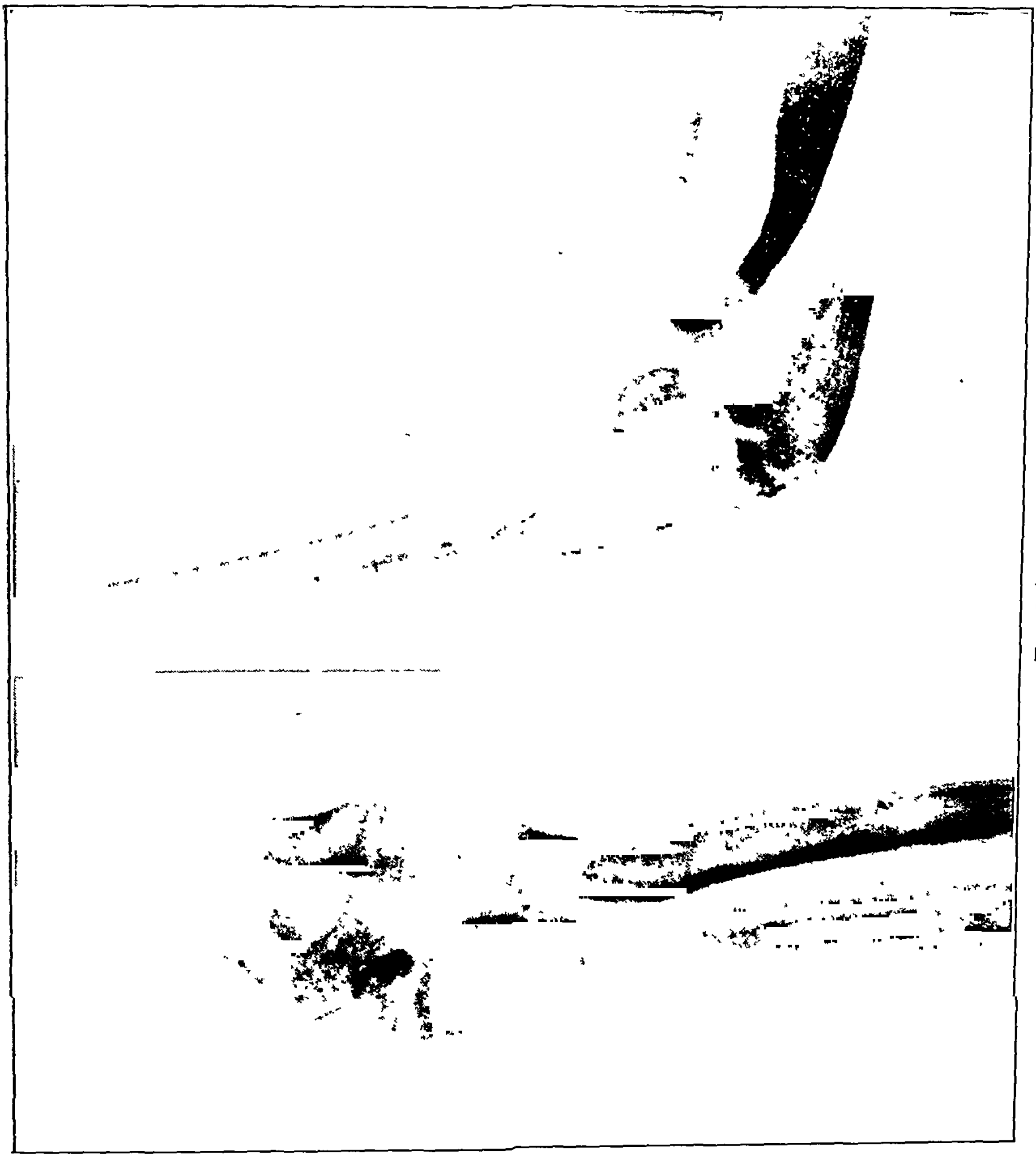

Fig. 2-A
Case 2. Fracture of the neck of the radius before reduction

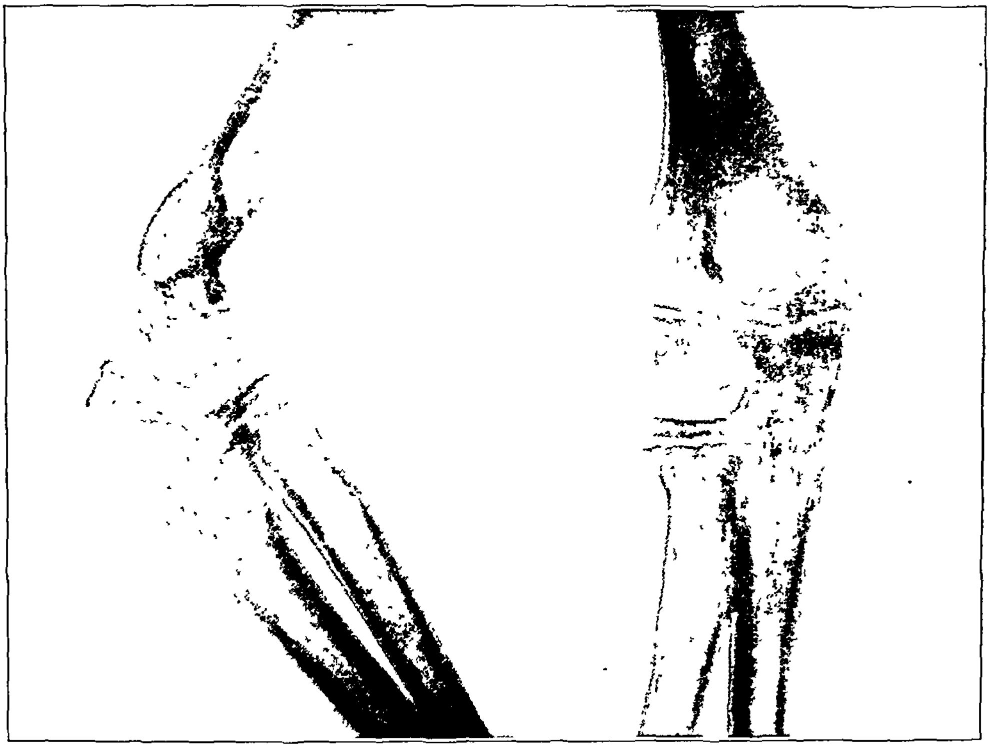

FIG. 2-C
Fracture of the neck of the radius fourteen weeks after reduction.

unprotected neck of the radius. The proximal fragment is displaced outward and forward. Occasionally the fragment is displaced outward and backward.

The manipulation is performed under general anaesthesia and roentgenographic control. Immediately after reduction, roentgenograms are made. Reduction is complete when the articular surfaces of the radius and capitellum are parallel. (In the event that reduction has been incomplete, a second and even a third attempt should be made. In Case 2, three attempts were necessary before a satisfactory reduction was obtained.) The extremity is immobilized in plaster for three weeks, with the elbow held in 90 degrees of flexion and the forearm in complete supination.

CASE REPORTS

Case 1. S.M., aged eight, sustained a fracture of the neck of the right radius on April 30, 1941. Under general anaesthesia the fracture was reduced by the Patterson manipulation. The elbow was immobilized in plaster for three weeks in 90 degrees of flexion, with the forearm in complete supination. On July 17, 1941, eleven weeks after reduction, there was a complete and painless range of motion of the right elbow and forearm. Roentgenograms (Fig. 1) made on September 14, 1944, show no evidence of the fracture, except the subperiosteal ossification of the neck of the radius as seen on the lateral view.

Case 2. R.E.B., aged seven, sustained a fracture of the neck of the right radius on June 16, 1944. The patient was first seen on the following day. Under general anaesthesia the fracture was manipulated and reduced by the Patterson manoeuvre. Figures 2-A and 2-B show the position of the proximal fragment before reduction (outward and backward displacement), and the complete replacement of the fragment immediately after reduction. The articular surfaces of the radial head and the capitellum were parallel. The elbow was immobilized in plaster, as described in Case 1, and the plaster was worn for three weeks. The patient was last examined on September 21, 1944, fourteen weeks after manipulation. She presented a complete and painless range of motion of the elbow and forearm.

Case 3. J.M., aged six, sustained a fracture of the neck of the left radius on June 20, 1944. Treatment already described was employed, and Figures 3-A, 3-B, and 3-C show the fracture before and after reduction.

FIG. 3-A
Case 3. Fracture of the neck of the radius before reduction.

FIG. 3-B
Fracture of the neck of the radius after reduction.

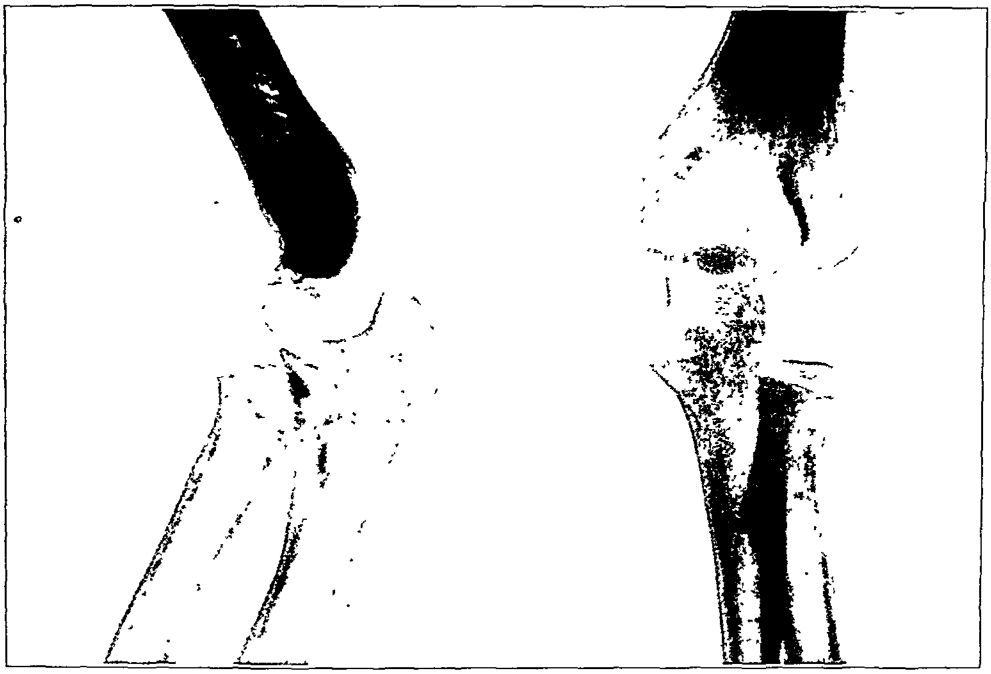

Fig. 3-C
Fracture of the neck of the radius fifteen weeks after reduction.

The patient was last examined fifteen weeks after manipulation. He presented a complete and painless range of motion of the elbow and forearm.

Case 4. H.R., aged nine, sustained a fracture of the neck of the left radius on June 21, 1944 (Fig. 4-A). The fracture was reduced four hours later under general anaesthesia by the Patterson manipulation. Figure 4-B, made immediately after reduction, shows the improved position of the displaced proximal fragment, but complete reduction has not been obtained. The articular surfaces of the radius and the capitellum were not

Fig. 4-A
Case 4. Fracture of the neck of the radius before reduction

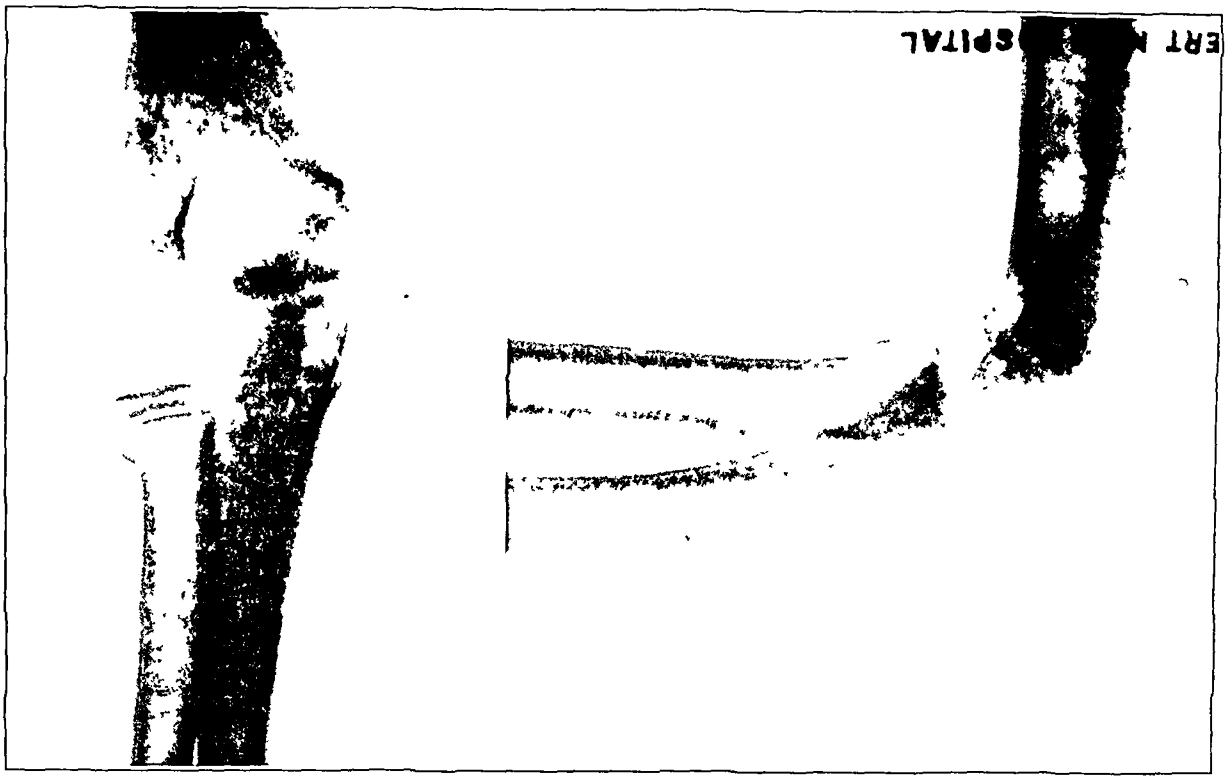

Fig. 4-B
Fracture of the neck of the radius after reduction.

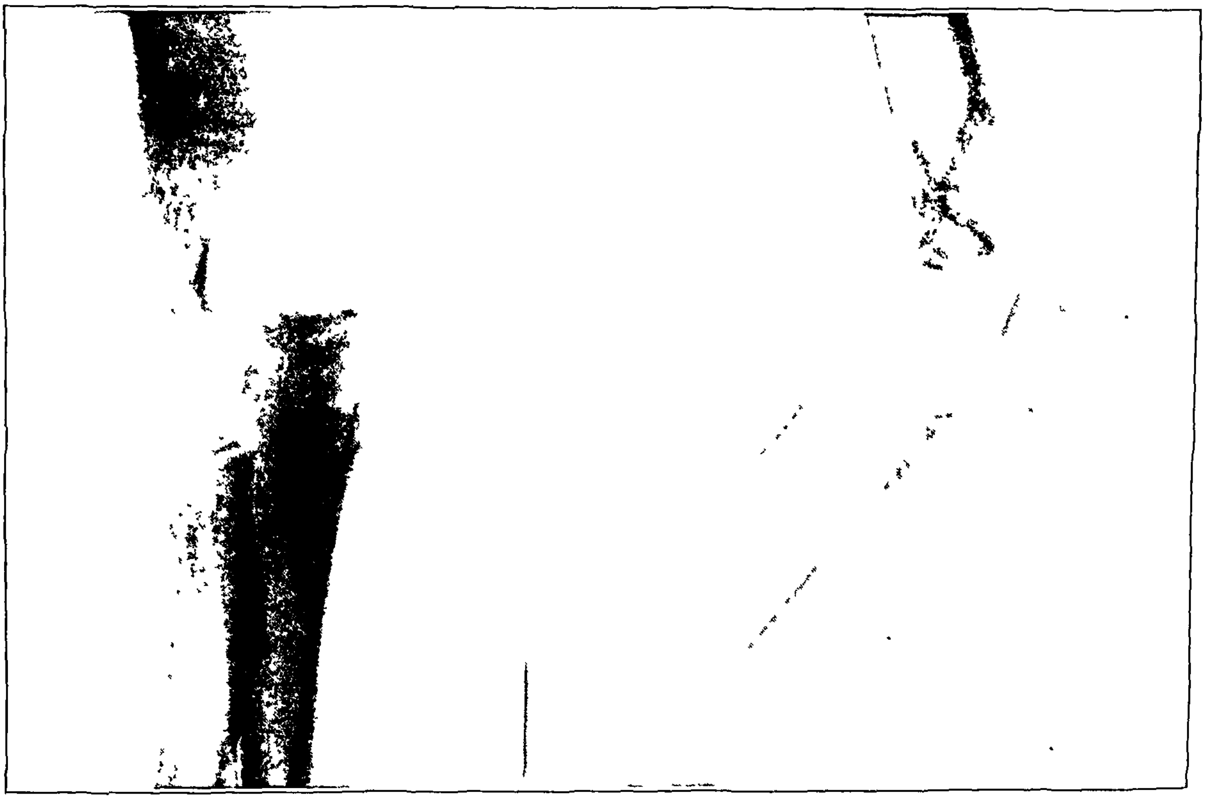

Fig. 4-C
Fracture of the neck of the radius fourteen weeks after reduction.

quite parallel. The elbow was immobilized in plaster for three weeks in 90 degrees of flexion with the forearm in complete supination. The patient was last examined on September 20, 1944. He did not complain of pain. Pronation and supination were complete, but there was 5 degrees of limitation of flexion and extension. Figure 4-C, made on September 29, 1944, shows that the improved position has been maintained fourteen weeks after manipulation. It is to be noted that the articular surfaces of the radius and the capitellum are not completely parallel.

SUMMARY

1. Four cases are reported of fracture of the neck of the radius in children with displacement of the proximal fragment in which satisfactory results were obtained by the Patterson manipulation.

2. It is recommended that this conservative treatment be tried in all similar cases before operative intervention is undertaken.

3. Every effort should be made to secure complete reduction. When the displaced fragment has been completely replaced, as evidenced by the parallel positions of the articular surfaces of the radius and the capitellum, complete motion is restored. When reduction has been incomplete, there is some residual limitation of motion, as in Case 4.

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WIRE FIXATION IN ACROMIOCLAVICULAR DISLOCATION

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Any inflexible immobilization used in the treatment of acromioclavicular dislocation should be of a temporary nature, since permanent rigid fixation of this joint, either by bony ankylosis or by the introduction of a foreign body into the tissues, is difficult to obtain and, when achieved, results in a disability as great as, or greater than, that which accompanies an unstable articulation.

Recent studies [1] on shoulder-joint function have clearly demonstrated the reason for the failure of operative procedures which attempt to make an unyielding union between the clavicle and the acromion. It has been shown that the clavicle, in addition to other motions usually attributed to it, rotates on its long axis up to 45 degrees when the arm is abducted to 180 degrees, and that restriction of the clavicular rotation may cause an inhibition of abduction at the shoulder joint even in the early phases of this motion.

In 1940, Murray reported a closed method of temporary wire fixation in acromioclavicular dislocations, and later Phemister modified the procedure by using threaded-wire fixation, combined with an open reduction. It is the purpose of the present paper to add to this method a simple means of maintaining reduction while the wires are being introduced, and to report on twenty patients treated in this way at the United States Naval Hospital in San Diego.

The degree of instability of the dislocations was varied, but in every instance there was definite disabling relaxation of the joint. In four patients, there was sufficient relaxation of the clavicle to determine that the coracoclavicular ligament had been com-

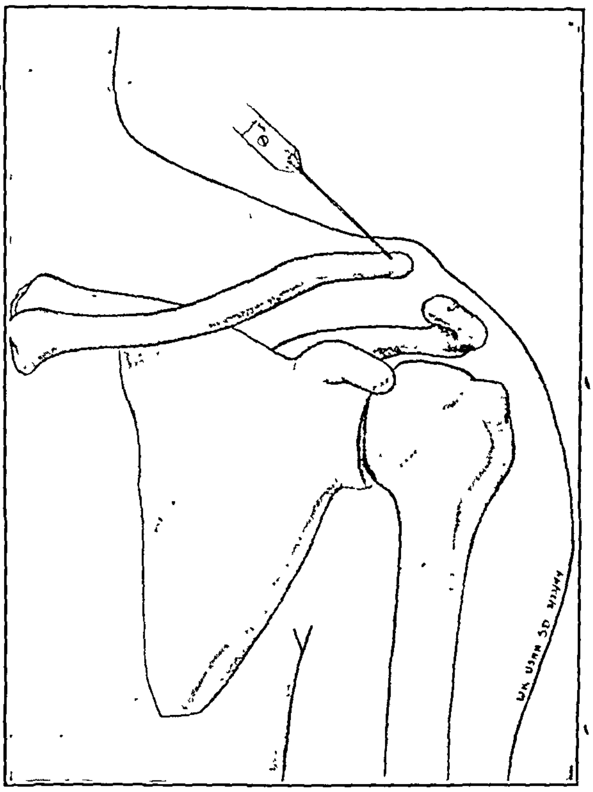

Fig. 1

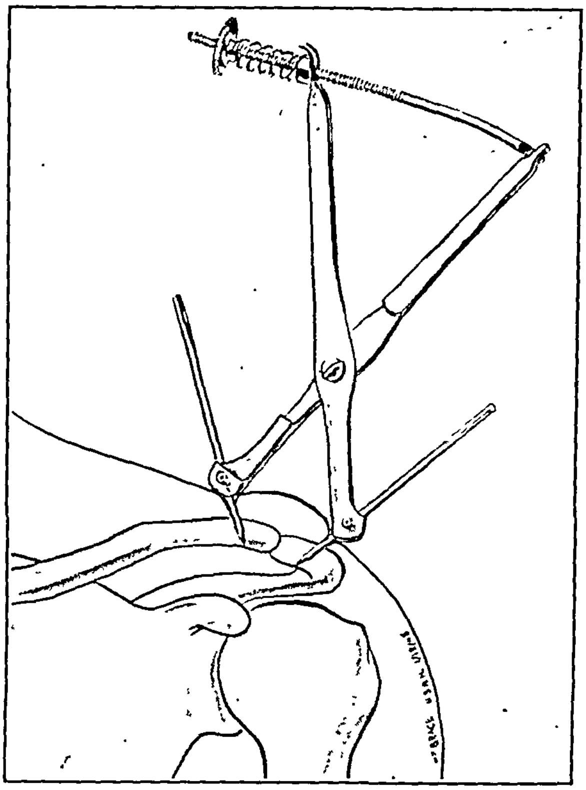

Fig. 2

Fig. 1: Placement of drill holes for towel clamp.
Fig. 2: A specially designed instrument replacing the towel clamp, maintaining reduction during the procedure. One-eighth inch Steinmann pins are used.

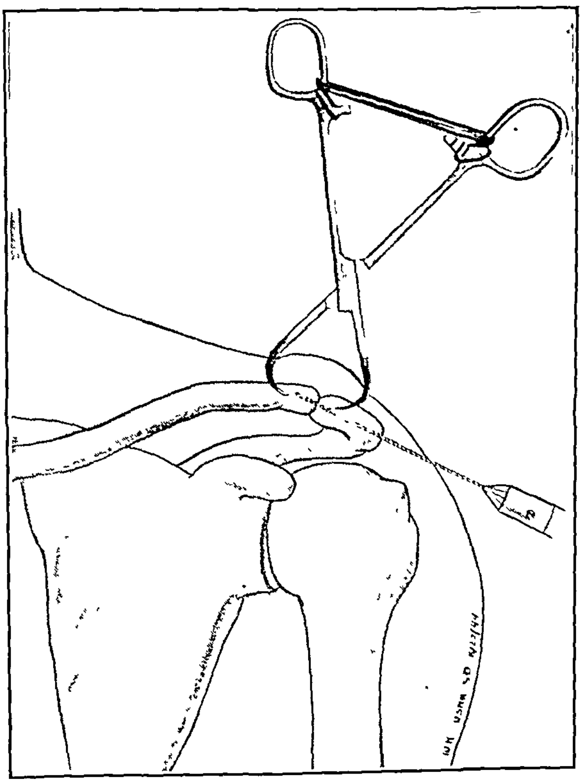

Fig. 3

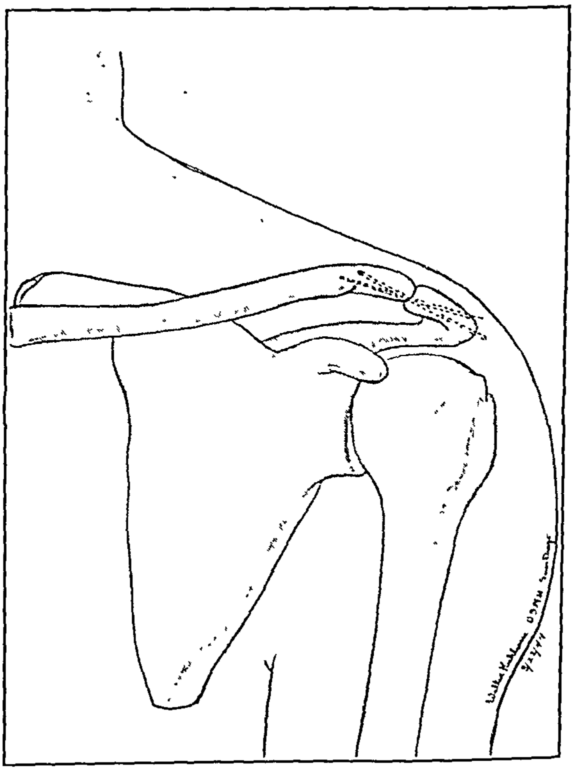

Fig. 4

Fig. 3: Anteroposterior check for position of first wire.
Fig. 4: Completed fixation with wires cut beneath the skin surface.

TABLE I

FIRST TWELVE CASES

Number	Name	Date of Injury	Days Between Injury and Fixation	Duration of Fixation (*Days*)	Interval Between Removal of Pins and Last Check-up (*Days*)
1	G.J.K.	Oct. 7, 1943	2	73	327
2	F.L.R.	Oct. 20, 1943	6	55	328
3	M.M.W.	Feb. 8, 1944	24	61	249
4	J.M.V.	Feb. 11, 1944	4	48	283
5	F.M.S.	Feb. 18, 1944	1	62	266
6	M.E.N.	Mar. 26, 1944	9	63	213
7	J.F.S.	Mar. 29, 1944	3	61	225
8	J.(n)T.	Apr. 5, 1944	20	66	105
9	M.M.B.	Apr. 25, 1944	4	66	285
10	D.R.B.	June 3, 1944	5	61	154
11	F.I.G.	June 22, 1944	2	58	152
12	H.J.D.	June 23, 1944	1	53	145
Average			7	61	228

pletely ruptured; while in one shoulder, the relaxation was so complete that it could be determined that all ligamentous and capsular structures on the distal third of the clavicle had been severed.

PROCEDURE

A general anaesthetic was used since it was thought that the injection of a local anaesthetic would distort the tissues and complicate the procedure.

The shoulder is prepared for the application of wires in the usual manner. A drill hole, 3/32 of an inch in diameter, is made through the superior cortex of the clavicle, one-half inch from the distal end. The hole is made at an angle of 45 degrees to the surface of the bone directed from the medial aspect laterally. A similar hole is drilled into the acromion opposite the joint, with the drill directed from the lateral aspect medially (Fig. 1).

The points of a towel clamp are inserted into the holes and held in position by a rubber band wound through the finger rings, with the loops hooked over the projecting snap lock. No attempt should be made to completely close the clamp. A more elaborate instrument was designed for this purpose (Fig. 2), and it has some advantages over the towel clamp and rubber band. By leverage on the clamp it is now an easy matter to place the clavicle and acromion in their normal relationship. While holding this position, a 3/32-inch pointed stainless-steel wire, nine inches long, is drilled from lateral to medial through the anterior portion of the acromion, across the joint space and down the medullary canal of the clavicle, for about one inch (Fig. 3). Roentgenograms in the anteroposterior and axillary projections are made at this time to check the accuracy of reduction and placement of the wire. (After experience with the procedure these control roentgenograms may be omitted. However, it is strongly urged that on the first few attempts, both views of the joint be taken.) A second wire is then inserted through the acromion, three-fourths of an inch posterior to the first. This wire is directed so that it also passes across the joint into the distal end of the clavicle. (At first some difficulty will be encountered when the wires are started into the flat, tapered, lateral edge of the acromion, but after a few trials this difficulty is overcome.) When the wires are in place, they are cut as short as possible by forcing the skin down with the blades of the cutter (Fig. 4). Two months later these wires are removed under a local anaesthetic through a small stab incision.

The degree of instability of the dislocations was varied, but in every instance there was definite disabling relaxation of the joint. In four patients, there was sufficient relaxation of the clavicle to determine that the coracoclavicular ligament had been com-

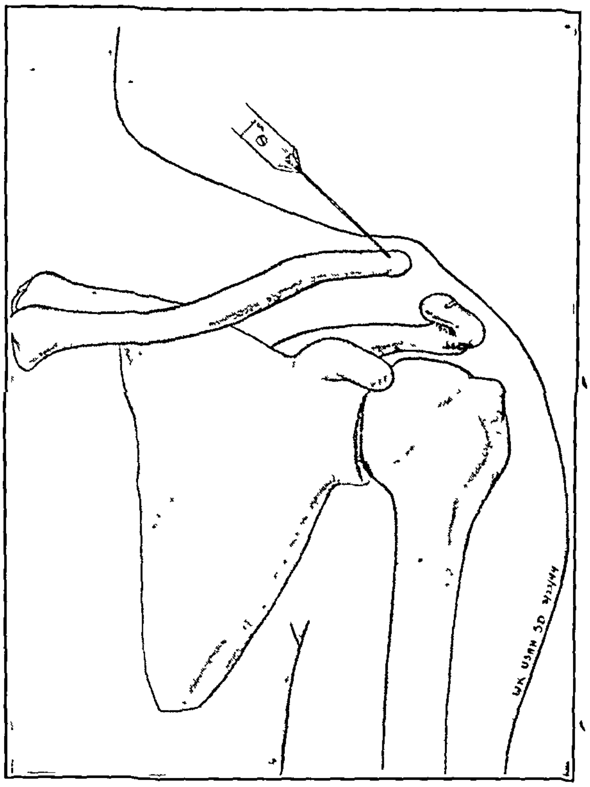

FIG. 1

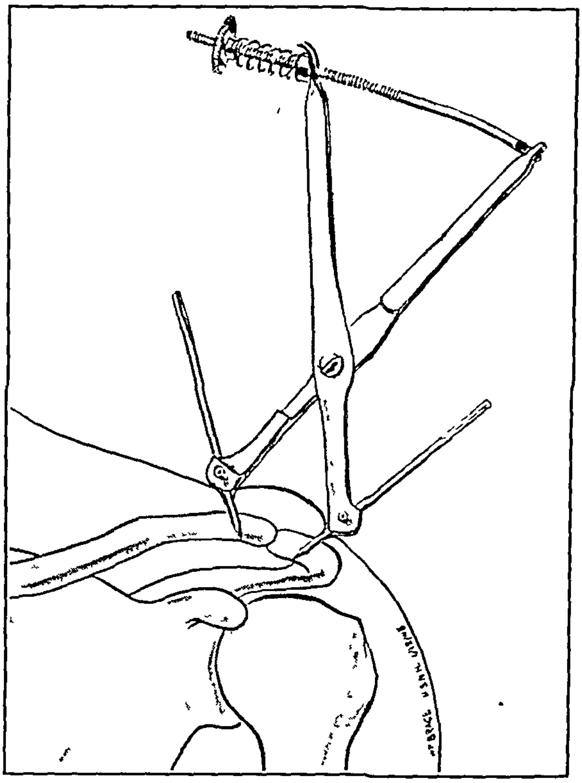

FIG. 2

Fig. 1: Placement of drill holes for towel clamp.
Fig. 2: A specially designed instrument replacing the towel clamp, maintaining reduction during the procedure. One-eighth inch Steinmann pins are used.

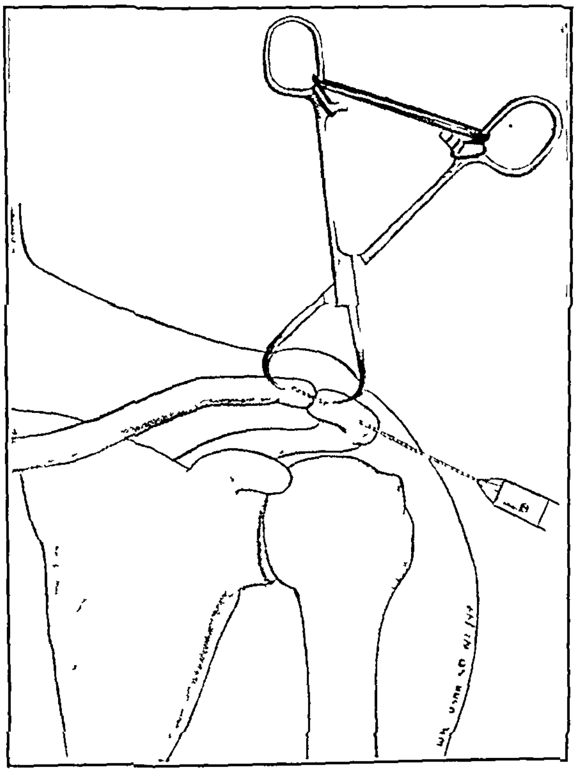

FIG. 3

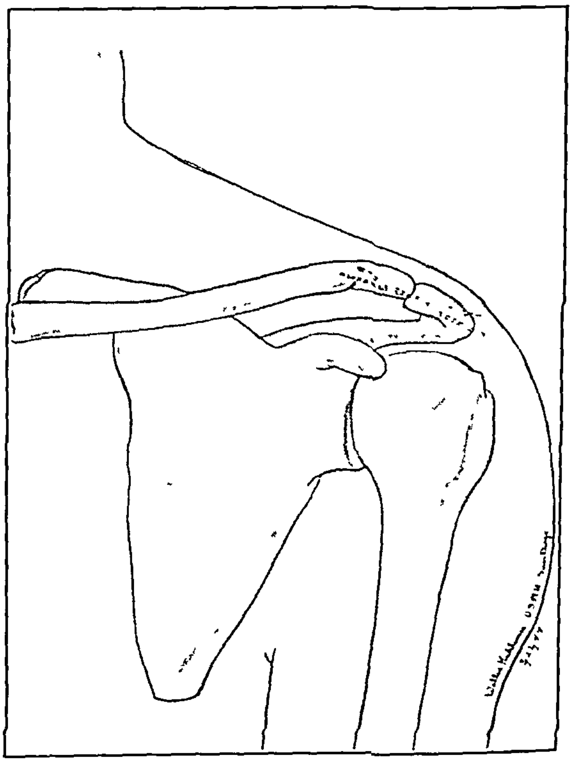

FIG. 4

Fig. 3: Anteroposterior check for position of first wire.
Fig. 4: Completed fixation with wires cut beneath the skin surface.

TABLE I

FIRST TWELVE CASES

Number	Name	Date of Injury	Days Between Injury and Fixation	Duration of Fixation (*Days*)	Interval Between Removal of Pins and Last Check-up (*Days*)
1	G.J.K.	Oct. 7, 1943	2	73	327
2	F.L.R.	Oct. 20, 1943	6	55	328
3	M.M.W.	Feb. 8, 1944	24	61	249
4	J.M.V.	Feb. 11, 1944	4	48	283
5	F.M.S.	Feb. 18, 1944	1	62	266
6	M.E.N.	Mar. 26, 1944	9	63	213
7	J.F.S.	Mar. 29, 1944	3	61	225
8	J.(n)T.	Apr. 5, 1944	20	66	105
9	M.M.B.	Apr. 25, 1944	4	66	285
10	D.R.B.	June 3, 1944	5	61	154
11	F.I.G.	June 22, 1944	2	58	152
12	H.J.D.	June 23, 1944	1	53	145
Average			7	61	228

pletely ruptured; while in one shoulder, the relaxation was so complete that it could be determined that all ligamentous and capsular structures on the distal third of the clavicle had been severed.

PROCEDURE

A general anaesthetic was used since it was thought that the injection of a local anaesthetic would distort the tissues and complicate the procedure.

The shoulder is prepared for the application of wires in the usual manner. A drill hole, 3/32 of an inch in diameter, is made through the superior cortex of the clavicle, one-half inch from the distal end. The hole is made at an angle of 45 degrees to the surface of the bone directed from the medial aspect laterally. A similar hole is drilled into the acromion opposite the joint, with the drill directed from the lateral aspect medially (Fig. 1).

The points of a towel clamp are inserted into the holes and held in position by a rubber band wound through the finger rings, with the loops hooked over the projecting snap lock. No attempt should be made to completely close the clamp. A more elaborate instrument was designed for this purpose (Fig. 2), and it has some advantages over the towel clamp and rubber band. By leverage on the clamp it is now an easy matter to place the clavicle and acromion in their normal relationship. While holding this position, a 3/32-inch pointed stainless-steel wire, nine inches long, is drilled from lateral to medial through the anterior portion of the acromion, across the joint space and down the medullary canal of the clavicle, for about one inch (Fig. 3). Roentgenograms in the anteroposterior and axillary projections are made at this time to check the accuracy of reduction and placement of the wire. (After experience with the procedure these control roentgenograms may be omitted. However, it is strongly urged that on the first few attempts, both views of the joint be taken.) A second wire is then inserted through the acromion, three-fourths of an inch posterior to the first. This wire is directed so that it also passes across the joint into the distal end of the clavicle. (At first some difficulty will be encountered when the wires are started into the flat, tapered, lateral edge of the acromion, but after a few trials this difficulty is overcome.) When the wires are in place, they are cut as short as possible by forcing the skin down with the blades of the cutter (Fig. 4). Two months later these wires are removed under a local anaesthetic through a small stab incision.

The men were advised not to use the shoulder in strenuous exercises, but no form of external immobilization was applied. It was known that several of the patients undertook rather severe types of physical exertion during the period of fixation, but few ill effects were noted.

RESULTS

In Case 15 the wires broke at the end of fifty-two days, and it was necessary to remove the proximal portion of the wires through an incision over the outer end of the clavicle; however, when the patient returned to full duty two months later, the joint was stable and painless. In approximately 25 per cent. of the cases, the wires loosened before the two-month period had elapsed and migrated toward the skin. In these cases the wires were simply pushed back, and the man was instructed to restrict the use of his arm until time for removal of the fixation.

Because of the nature of the Service, it is impossible to communicate with many of these men after they return to duty. However, the interval given in the last column in Table I was determined by the fact that those who had returned to duty were still in that status. It can be reasonably assumed that if the shoulders had been causing any appreciable discomfort, these men would not be carrying out the strenuous and exacting duties of their ratings.

Twelve of the men have been returned to full duty. At the time of their discharge from the hospital, all had complete range of motion in the shoulder joint. Four complained of some discomfort in the extremes of abduction, but the pain was not severe enough to constitute a disability. Five additional cases are ready for full duty as far as the acromioclavicular joint disability is concerned, but they are prevented from returning by complicating factors. M. M. W. (Case 3) was assigned to limited duty, because of a disability resulting from a fractured tibia. In Case 11, an acute febrile disease developed, from which the patient is now convalescing. Of the more recent cases (not included in Table I), one patient has not returned to duty because of conditions other than medical; another patient has a complicating vertebral compression fracture; and a third patient had a stable joint with a full range of shoulder motion when last seen, but was transferred to another duty and follow-up observations cannot be made.

J. T. (Case 8) remained on duty for three months following his discharge from the hospital. He then fell down stairs and re-dislocated the same acromioclavicular joint. He was not seen for treatment until eight weeks following this second injury. In the patient's estimation, the second injury was more severe than the injury causing the original dislocation. The pins were replaced, but the elapsed time was considered too great for simple healing, and an operative repair of the coracoclavicular ligament was done at the same time. The end result of the second injury has not been determined.

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SURGICAL APPROACHES TO THE KNEE JOINT *†

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In the development of surgical approaches, one of two methods is usually employed. The first method might be termed the approach which is planned to avoid the exposure of vital structures; and the second, the approach which is designed to expose them. In the first case, the incision is placed at sufficient distance from vital structures to obviate the necessity of their exposure. This method is to be recommended if adequate exposure of the lesion or lesions can be secured, and if there is only a remote possibility of injury to vital structures. The writers, however, stress the importance of the use of the second method in all instances where the incision is planned to give the most direct access to the site of the pathological changes, regardless of the proximity of vital structures. In such cases, the exposure of those structures in the path of the dissection, or in the immediate vicinity, is the paramount issue. Failure to observe this fundamental principle, the necessity for exposure, may result either in a permanent loss of function or in a surgical disaster. The operating surgeon should be so familiar with the anatomy that he can plan his own approach, basing it upon the anatomical accessibility of the lesion. This fundamental knowledge of anatomy is most important in the surgery of bones and joints. Before proceeding with a description of the surgical approaches to the knee joint, therefore, some pertinent, general anatomical considerations are essential.

GENERAL ANATOMICAL CONSIDERATIONS

The knee joint, the largest articulation in the human body, is formed by the condyles of the femur, the tuberosities of the tibia, and the patella. From the standpoint of its bony architecture, it is a weak joint. For strength and stability it is dependent upon its supporting structure,—the fibrous capsule, reinforced by ligaments and muscles.

Capsule

It is difficult to find a satisfactory description of the capsule of the knee in textbooks of anatomy and surgery. It is often described as a continuous structure of fibers, completely investing the joint; whereas the true fibrous portion of the capsule exists only on its posterior aspect, where it extends from the proximal margin of the articular surface of the femur and intercondylar line to the posterior border of the head of the tibia. Added strength is given to this part of the capsule by the oblique popliteal ligament, which extends upward and outward across the posterior part of the joint to the medial border of the lateral condyle of the femur. Further reinforcement is obtained laterally by a thickened portion of the capsule, which bridges the penetrating tendon of the popliteus muscle, attaching itself above to the posterior aspect of the femoral epicondyle and below by two slips,—one to the head of the fibula, and another to the margin of the tibial condyle. Additional support is provided to the fibrous capsule by the collateral and the cruciate ligaments.

In contradistinction to the posterior part of the capsule, the anterior portion is ill-defined. It is composed of the quadriceps tendon, the patella, the infrapatellar tendon, and the blending of the fascia lata with the fibrous aponeuroses of the vasti muscles. A detailed description of these structures will be given under the section on approaches to

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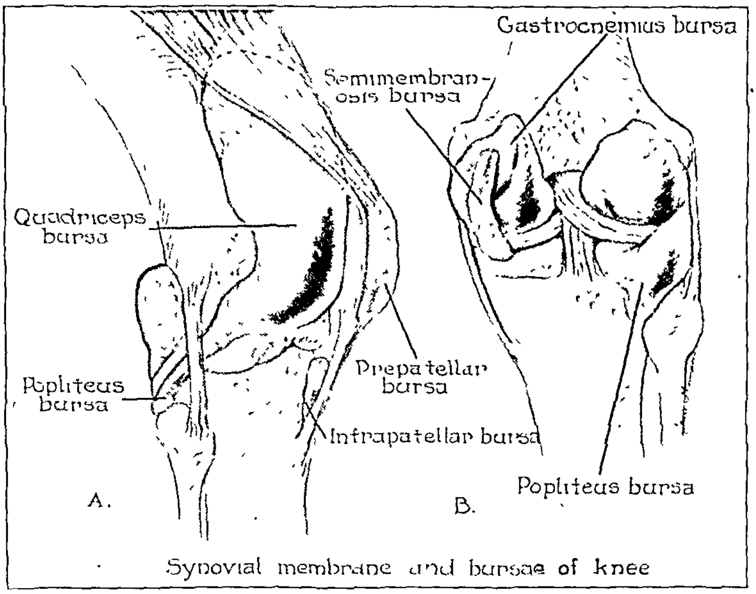


FIG. 1

A: Anterolateral aspects of the knee joint (Redrawn from Spalteholz).
B: Posterior aspect of the knee joint (Sweet).

the anterior aspect of the knee joint.

Synovia and Bursae

The synovial membrane lines the aponeurotic and the fibrous portions of the capsule. It extends upward beyond the articular surface of the distal end of the femur, on the anterior aspect of the joint, in the form of a cul-de-sac which lies under cover of the tendon of the quadriceps muscle. The upper part of this cul-de-sac usually communicates with the suprapatellar bursa. A pouchlike extension or diverticulum is prolonged posteriorly and distally on the tendon of the popliteus muscle. This diverticulum sometimes communicates with the capsule of the upper tibiofibular joint. A second pouch of synovial membrane often connects with a bursa which lies between the tendon of the semimembranosus and the tendon of origin of the inner head of the gastrocnemius (Fig. 1).

In the posterior part of the joint, the cruciate ligaments are enveloped in a duplication of the synovial membrane which renders them extrasynovial. The infrapatellar fat pad, triangular in shape, lies between the distal part of the patella and the upper, anterior margin of the tibia. It is rendered extrasynovial by a fold of synovial membrane, the lateral free margins of which extend to the intercondylar notch and are known as the ligamenta alaria. The central portion of this ligamentous fold is known as the ligamentum mucosum.

The semilunar cartilages (menisci) lie between the outermost portions of the articulating surfaces of the femur and the upper end of the tibia. They are wedge-shaped structures, free at their inner margins, but attached to the tibia at their outer surfaces by the coronary ligaments. Each cartilage presents two extremities or horns, which are fixed by fibrous attachments to the intercondylar eminence on the upper surface of the tibia (Fig. 2).

The numerous bursae about the knee joint are described in detail in various textbooks of anatomy. In this paper, the writers will deal briefly with those of constant occurrence and of surgical importance. On the anterior aspect of the knee, there are the so-called prepatellar bursae, which lie between the skin and the anterior surface of the patella and the patellar ligament. There are two others, termed the superficial and deep infrapatellar bursae; the former lies between the skin and infrapatellar tendon, while the latter lies between the tendon and the anterior surface of the upper end of the tibia. On the lateral side of the joint, there are usually four bursae,—one between the lateral head of the gastrocnemius and the capsule, another between the fibular collateral ligament and the tendon of the biceps, a third between the fibular collateral ligament and the tendon of the popliteus, and a fourth between the tendon of the popliteus and the lateral condyle of the femur; the fourth bursa is usually a direct extension of the synovial membrane of the joint. On the medial side of the joint, a bursa lies between the medial head of the gastrocnemius and the tendon of the semimembranosus, and often communicates with the knee joint; a second bursa lies superficially between the tibial collateral ligament and the tendons of the sartorius, gracilis, and semitendinosus; while a third is placed beneath the tendon of the semimembranosus at its attachment to the head of the tibia.

In addition, Brantigan and Voshell describe bursae which lie in relation to the tibial collateral ligament; as many as three of these bursae have been found in a single joint. The principal locations of these bursae are: (a) between the tibial collateral ligament and the capsule of the joint, (b) between the tibial collateral ligament and the medial meniscus, (c) directly over the meniscus, (d) inferior to the meniscus, and (e) between the tibial collateral ligament and the tibia, but not related to the meniscus.

Blood Supply

The blood supply to the knee joint and its surrounding structures is furnished by the genicular branches of the popliteal artery, the arteria genus suprema, a branch of the femoral artery, the descending branch of the lateral circumflex artery, and the recurrent branch of the anterior tibial artery. The terminals of these vessels form a rich network over the bones, ligaments, and tendons, and are arranged in three arterial arches on the anterior aspect of the joint. The uppermost of these arches lies in the midst of the superficial fibers of the quadriceps muscle, near the upper border of the patella. The two lower arches are directed transversely through the fatty tissues behind the patellar ligament. The superomedial and superolateral genicular arteries are given off by the popliteal artery proximal to the intercondylar notch. They pass inward and outward beneath the hamstring tendons directly upon the femur, pierce the inner and outer intermuscular septa, and anastomose in the vastus medialis and vastus lateralis, respectively, with the arteria genus suprema and the descending branch of the lateral circumflex artery. The inferomedial and inferolateral genicular arteries are given off from the popliteal artery at the level of the lower border of the oblique popliteal ligament. They pass inward and outward close to the bone, with the inferomedial passing along the upper border of the popliteal muscle and beneath the tibial collateral ligament. The inferolateral genicular artery passes along the upper border of the fibular head of origin of the soleus, around the neck of the fibula, and then beneath the fibular collateral ligament. The recurrent branch of the anterior tibial artery is given off after this main vessel has passed through the interosseous membrane. It proceeds upward to join in the anastomosis on the anterior aspect of the joint (Fig. 3).

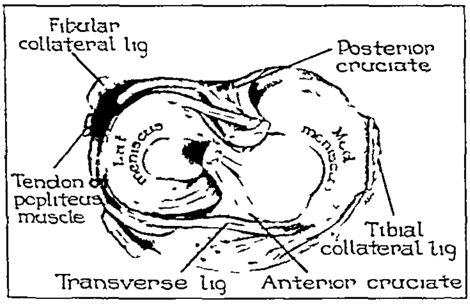


FIG. 2
The upper surface of the tibia, showing the relationship of the semilunar cartilages and the cruciate ligaments (Redrawn from Grant's Atlas of Anatomy).

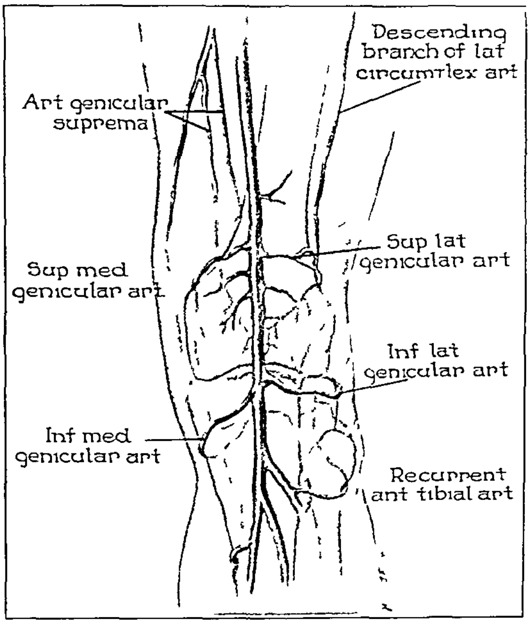


FIG. 3
An anatomical sketch, showing the collateral circulation about the knee.

Cutaneous Nerves

The nerves which supply the skin over the various aspects of the knee are:

1. Anterior division of the lateral cutaneous nerve of the thigh.
2. Intermediate cutaneous nerve of the thigh.
3. Anterior and posterior divisions of the medial cutaneous nerve of the thigh.
4. Saphenous nerve.
5. Posterior cutaneous nerve of the thigh.
6. Posterior cutaneous nerve of the leg.
7. Lateral cutaneous nerve of the leg.
8. Anastomotic peroneal nerve of the leg (Fig. 4).

An accurate anatomical knowledge of the cutaneous nerves is of importance to the surgeon, because their severance may cause temporary or permanent disturbance of sensation, or may lead to the formation of painful neuromata. Division of the infrapatellar branch of the saphenous nerve at the time of an operation for removal of the internal semilunar cartilage (medial meniscus) may cause a painful neuroma with symptoms which are similar to those for which the cartilage was removed. The writers have seen several such cases, in which removal of the neuromata gave complete relief of symptoms. These cutaneous nerves are of further significance, because the operating surgeon can use them as anatomical landmarks and guides to deeper structures. For example, the posterior cutaneous nerve of the calf can be traced to its origin from the posterior tibial nerve. A needless and often prolonged search in the popliteal fat for the sciatic nerve and its divisions and the popliteal vessels is thus avoided. A further description of the various cutaneous nerves about the knee will be given in the appropriate sections.

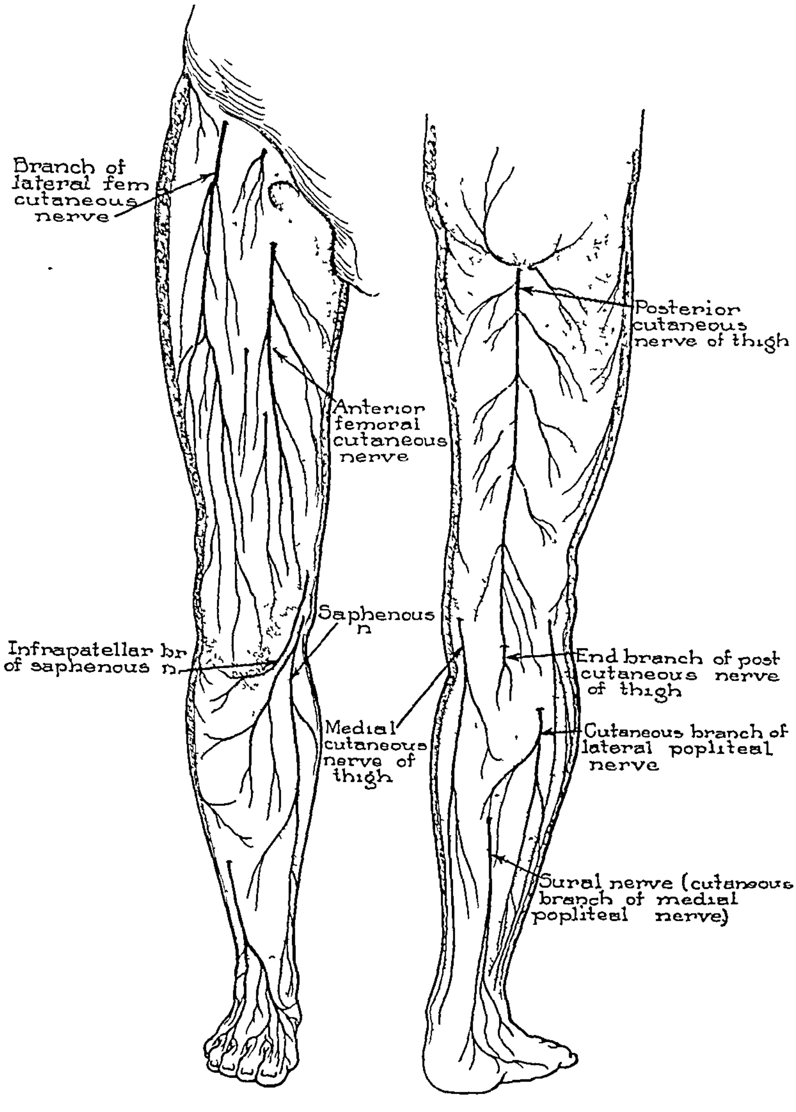


Fig. 4
The cutaneous nerves of the lower extremity.

SURGICAL APPROACHES

The surgical approaches to the knee joint will be described according to the following outline:

I. Approaches to the Anterior Aspect of the Knee Joint (Fig. 6).
   A. The parapatellar incisions.
      1. The median parapatellar incision (von Langenbeck).
      2. The S-shaped parapatellar incision (Payr).
      3. The oblique parapatellar incision (Erkes).
      4. The lateral parapatellar incision (Kocher).

B. Incisions which divide the patella.
  1. Vertical division of the patella (Brackett and Hall, Jones).
  2. Transverse division of the patella (von Volkmann).
  3. Sagittal division of the patella (Devine).
  4. Oblique division of the patella (Bougot and De La Rue).
C. Incisions which divide the tendon of the quadriceps muscle.
  1. Plastic division of the quadriceps tendon (Putti, Campbell).
  2. Plastic division of the quadriceps tendon (Coonse and Adams).
D. Incisions which divide the tendon of the patella transversely.
  1. The U-shaped incision (Textor).
  2. The H-shaped incision (Ollier).

II. Approaches to the Medial Aspect of the Knee Joint.
  A. The S-shaped incision.
  B. The straight or curved incision.

III. Approaches to the Lateral Aspect of the Knee Joint.
  A. The S-shaped incision.
  B. The straight or curved incision.

IV. The Approach for the Removal of the Semilunar Cartilages (the Menisci).
  A. Partial removal of the internal semilunar cartilage.
  B. Complete removal of the internal semilunar cartilage.
  C. Partial removal of the external semilunar cartilage.
  D. Complete removal of the external semilunar cartilage.

V. Bilateral Incisions.
  A. Exposure of the popliteal face of the femur (Henry).
  B. Approach for epiphyseodesis (Abbott and Gill).
  C. Removal of loose bodies from the posterior compartment of the knee (Henderson).
  D. Posterior capsulotomy in flexion contractures of the knee (Wilson).

VI. Approaches to the Posterior Aspect of the Knee Joint.
  A. The mid-line approach through the popliteal space.

VII. Approaches for Drainage of Sepsis of the Knee Joint.
  A. Parapatellar approaches.
    1. Vertical (single, multiple, bilateral).
    2. Horizontal (bilateral).
  B. U-shaped incision.
  C. Posteromedial, tibial incision.
  D. Posteromedial, femoral incision (Klein).
  E. Incisions for counter-drainage on the posterolateral aspect of the knee.

Approaches to the Anterior Aspect of the Knee Joint

Surgical Anatomy: The quadriceps tendon is subdivided into three parts, readily dis-rnible in a sagittal section through the middle of the patella (Fig. 5). The anterior sub-vision is the tendon of insertion of the rectus femoris, while the intermediate subdivision the common tendon of the vastus medialis and the vastus lateralis, and the posterior bdivision is the tendon of the vastus intermedius. The genu articularis muscle joins the ndon of the vastus intermedius, and also provides a slip which inserts into the apex of the prapatellar synovial pouch. Between the adjacent margins of the vasti, a fascial sling formed, which acts as a hammock or cradle for the tendon of the rectus femoris. This ng, traced laterally, blends with the aponeuroses of the vasti muscles. The aponeurosis the lower margin of the vastus medialis divides into two distinct layers over the anter-nedial aspect of the knee. The anterior layer passes across the patella in the form of a ntinuous sheet which blends with the aponeurosis of the vastus lateralis. Below the

level of the tibial tubercle it becomes continuous with the deep fascia of the leg. The posterior or deep layer of the aponeurosis of the vastus medialis is inserted into the medial border of the patella and the upper margin of the tibia. The synovial membrane lies behind this layer. On the outer aspect of the knee, the deep fascia and aponeurosis blend to form a single layer which is inserted into the lateral margin of the patella and the upper border of the tibia. This layer fuses with the iliotibial band and the fascia enclosing the biceps muscle. The operating surgeon should note the various fascial layers which facilitate exposure of the joint and closure of the wound. On the anteromedial surface, four layers of fascia are found,—namely, the superficial fascia, often indistinct and of little importance, the fascia lata, sometimes blended with the anterior layer of the aponeurosis of the vastus medialis, and the deep layer of the aponeurosis of the vastus medialis. On the anterolateral aspect of the knee, the blending of the fibrous aponeurosis with the iliotibial tract is so intimate that only two layers are distinguishable, the superficial fascia and a layer of deep fascia and fibrous aponeurosis (Saunders).

The important landmarks are the quadriceps tendon, the patella, the patellar tendon, the condyles of the femur, and the tuberosities of the tibia. With the knee in extension, the quadriceps tendon forms an obtuse angle with the patella and the patellar tendon of approximately 170 degrees (Callander). Curvilinear incisions are, therefore, preferable for those approaches in which either the patella or the aponeurotic expansions of the vasti are divided to enter the joint. With the knee in flexion, the iliotibial tract and the biceps tendon stand out prominently as they pass to their respective insertions into the lateral margin of the tibia and the head of the fibula. On the posteromedial surface of the joint the tendons of the sartorius, gracilis, and semitendinosus are seen where they insert into the medial aspect of the upper end of the tibia.

A. *The Parapatellar Incisions*

1. The median parapatellar incision (von Langenbeck).

a. *Indications:*

(1) Exploration of the joint;
(2) Synovectomy;
(3) Osteochondritis dissecans;
(4) Removal of loose bodies (joint mice);
(5) Repair of the cruciate ligaments;
(6) Removal of the infrapatellar fat pad.

b. *Position of the patient:* The patient is supine with the knee on a sandbag and flexed from 20 to 30 degrees.
(NOTE: The position of the patient and the same anatomical landmarks are used in all median parapatellar incisions.)

c. *Landmarks:*

(1) Tibial tubercle;
(2) Patellar tendon;
(3) Patella;
(4) Quadriceps tendon;
(5) Vastus medialis;
(6) Adductor tubercle.

d. *Incision:* The incision of the skin is begun over the medial portion of the quadriceps tendon, four inches above the upper border of the patella (Fig. 6, *C*). It is continued downward in a gentle curve following the medial margin of the quadriceps tendon, the medial border of the patella, and the patellar tendon. It next crosses the upper end of the tibia, and ends inferior to the tubercle of the tibia. One of two methods of exposure of the joint may be followed. *In the first method,* the deep fascia is incised and the quadriceps tendon is defined. This tendon is split in a vertical direction one-third of an inch lateral to its medial border. The incision is continued downward with division of the

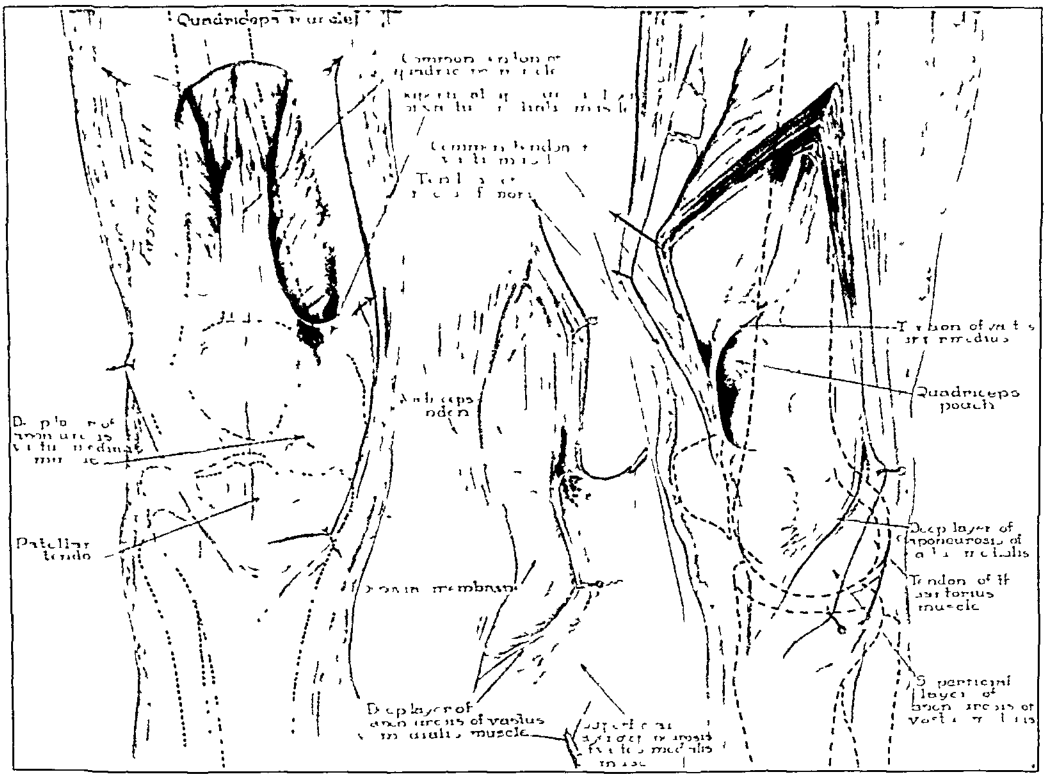


FIG. 5
Anatomical dissections, showing the three divisions of the quadriceps tendon, the synovial membrane, the quadriceps pouch, and the aponeurotic insertions of the vasti muscles into the patella and tibia.

aponeurosis of the vastus medialis following the medial border of the patella and the patellar tendon. Just below the tubercle of the tibia, the periosteum is divided obliquely and reflected laterally for a short distance to free only the medial portion of the insertion of the patellar tendon. This procedure facilitates displacement of the patella.

An alternate method is described by Fisher, in which the skin is reflected laterally until the lateral margin of the patella is reached. A straight incision is then made through three layers of fascia over the quadriceps tendon, the patella, and the patellar tendon (Fig. 7). These three layers are the superficial fascia, the fascia lata, and the superficial layer of the aponeurosis of the vastus medialis. Medial to the patella the deep fascia and superficial layer of the aponeurosis blend and are generally reflected as one layer. The deep layer of the fibrous aponeurosis is now seen as a solid sheet, though infrequently it is in the form of cords or retinacula. The synovia and deep apondurosis are divided medial to the patella, and the quadriceps tendon is separated in the line of its fibers just lateral to the insertion of the vastus medialis (Fig. 8). The patellar tendon is freed along its medial border to the level of the tibial tubercle, exposing the infrapatellar bursa. The patella is dislocated laterally to expose the interior of the joint. Greater access to the joint may be secured in four ways: (1) by division of the quadriceps tendon to a higher level, (2) by turning the upper end of the incision obliquely inward and separating the fibers of the vastus medialis, (3) by vertical section of the medial border of the alar ligament and adjacent fat pad, and (4) by freeing the patellar tendon subperiosteally on its medial aspect.

The structures which are exposed are:

(1) Quadriceps pouch;
(2) Condyles of the femur;
(3) Posterior surface of the quadriceps tendon, and the posterior surfaces of the patella and the patellar tendon;

(4) Infrapatellar fat pad;
(5) Ligamentum mucosum;
(6) Origin of the anterior cruciate ligament and the insertion of the posterior cruciate ligament (Fig. 9);
(7) Anterior margins of the upper end of the tibia and the semilunar cartilages.

The wound is closed with interrupted sutures to the deep layers of the fibrous aponeurosis and synovial membrane, to the fascia lata and the superficial layer of the fibrous aponeurosis directly over the center of the patella, and to the skin.

2. An S-shaped parapatellar incision has been described by Payr. The incision of the skin is begun four inches above the upper border of the patella, and is then curved

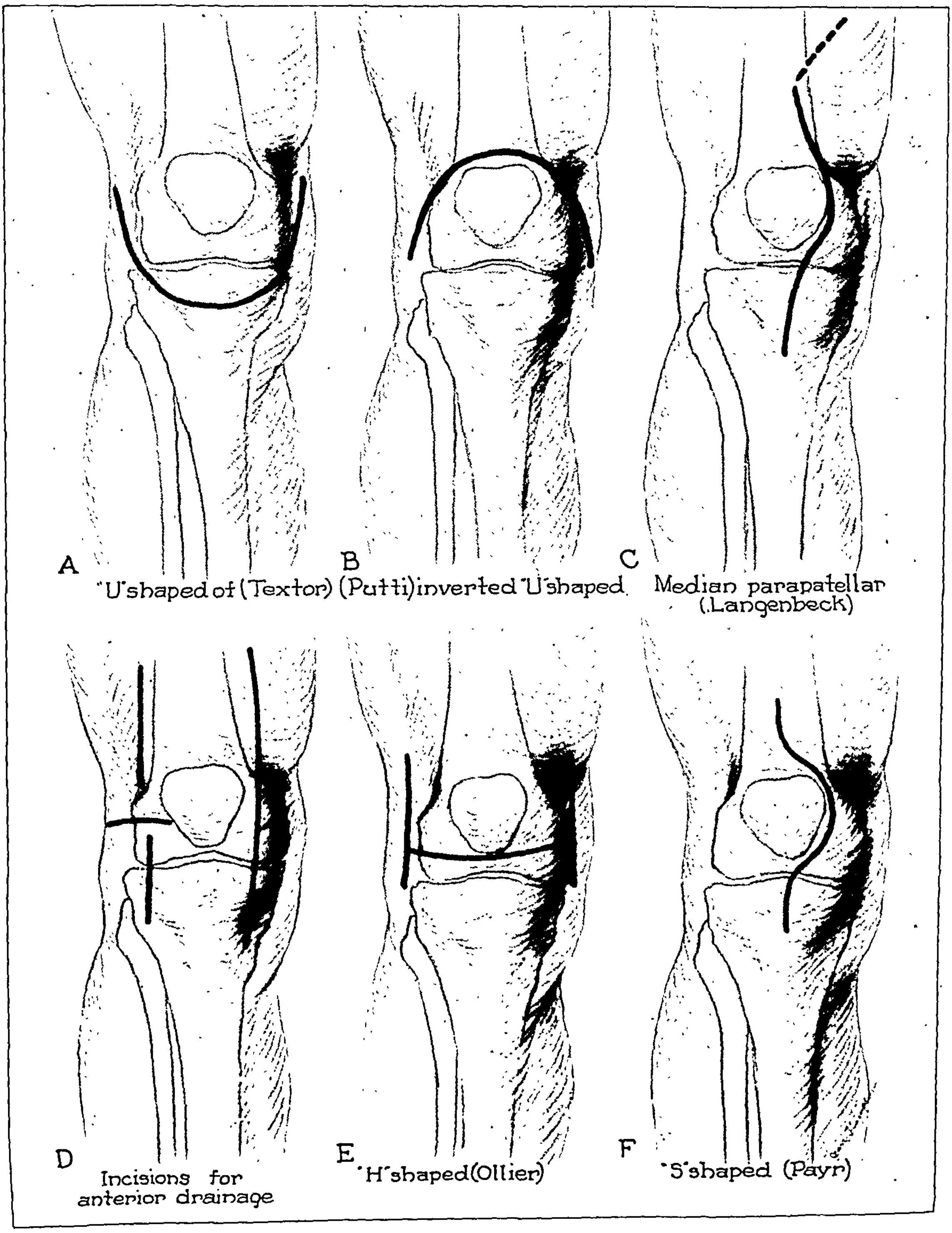
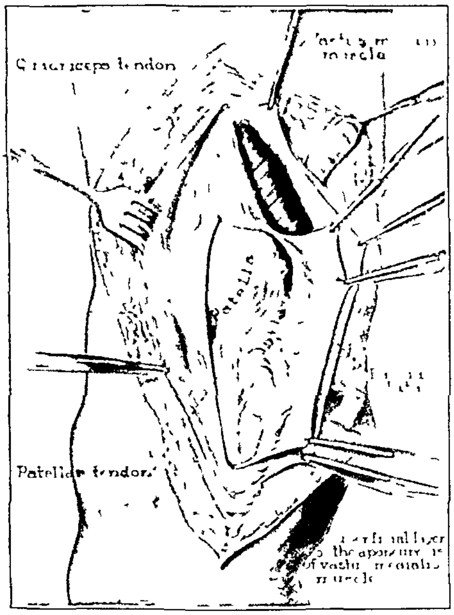


Fig. 6
The incisions on the anterior aspect of the knee.



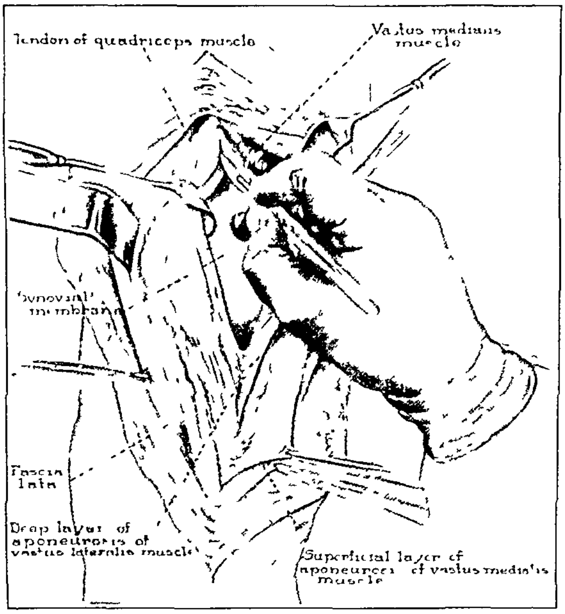


FIG. 7 FIG. 8

Fig. 7: The medial parapatellar incision, showing fascia lata and the superficial layer of the aponeurosis of the vastus medialis muscle, reflected from the anterior surface of the patella.

Fig. 8: The medial parapatellar incision, showing the fascia lata and the aponeurotic layers.

around its medial border to follow the medial margin of the patellar tendon to the tibial tubercle. The fibrous insertions of the vastus medialis into the quadriceps tendon are divided, and the fibrous aponeurosis of the vastus medialis is divided down to the level of the insertion of the patellar ligament into the tibial tubercle. The synovial membrane is then incised, and the patella is displaced to gain access to the joint.

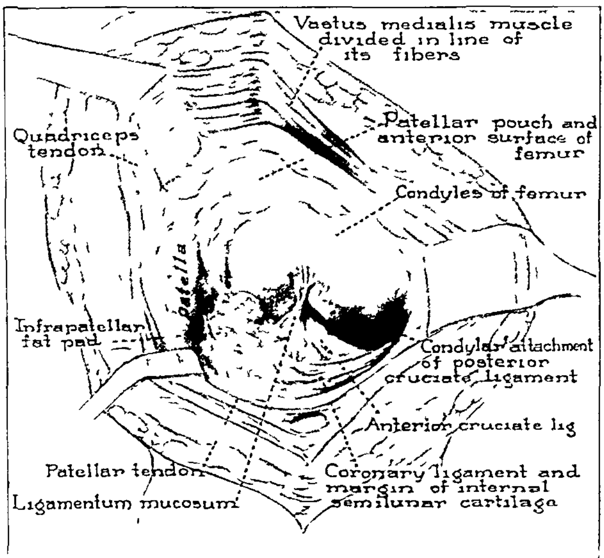


FIG. 9

The structures which are exposed by the median parapatellar incision after the displacement of the patella.

3. The Erkes incision follows the grain of the skin (Fig. 10, *A*). It is begun on the medial surface of the medial epicondyle of the femur, and is continued downward across the anteromedial aspect of the joint to reach the insertion of the patellar tendon into the tibial tubercle. The fibers of origin of the vastus medialis are freed from the internal intermuscular septum to permit displacement of the patella, and thus obtain access to the joint. Erkes contends that by this method, together with stretching of the vastus medialis, he avoids division of the aponeurotic insertion of this muscle.

4. Lateral parapatellar incision of Kocher (Fig. 10, *B*).

a. *Indications:*

(1) Exploration of the anterolateral aspect of the joint;
(2) Removal of loose bodies;
(3) Treatment of certain fractures in the lower end of the femur

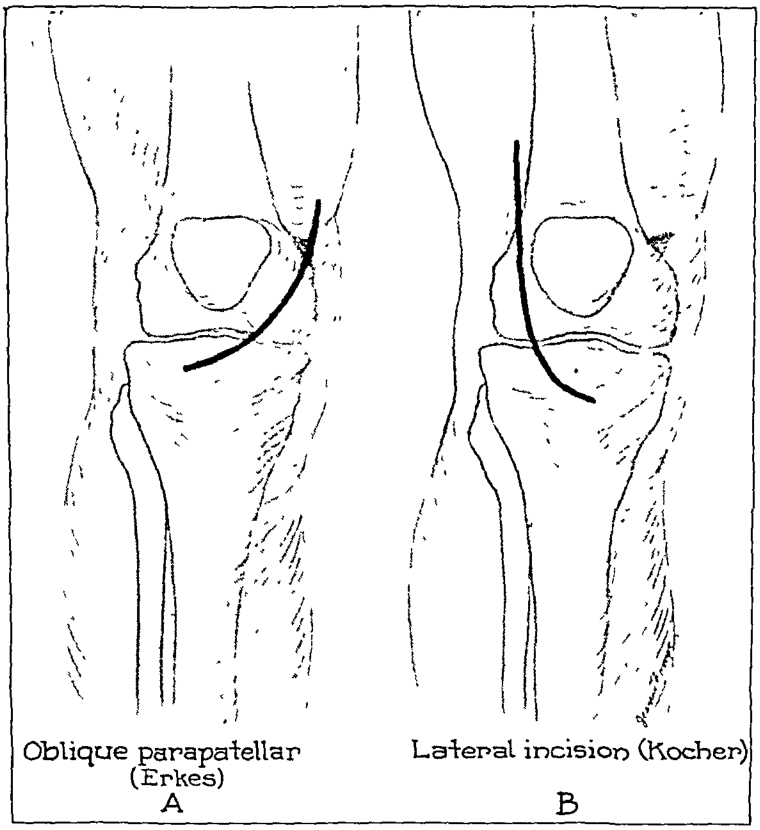


FIG. 10
A: The oblique parapatellar incision of Erkes.
B: The lateral incision of Kocher.

b. *Landmarks:*
(1) Tibial tubercle;
(2) Patellar tendon;
(3) Patella;
(4) Quadriceps tendon;
(5) Vastus lateralis;
(6) External condyle of the femur.

c. *Incision:* The incision is begun over the vastus lateralis on the lateral aspect of the joint. It is continued downward over the parapatellar region, and then curved forward over the tibial tubercle. The fibrous aponeurosis of the vastus lateralis and the synovial membrane are divided in much the same manner as in the medial parapatellar incision. In order to facilitate a medial displacement of the patella, the patellar tendon is freed subperiosteally or subcortically from the tibial tubercle.

The criticism of this method, made by Putti, is that sectioning of the bone to free the insertion of the patellar tendon into the tibial tubercle may be followed by non-union. Albee modified the Kocher approach by dovetailing the bone at the site of the insertion of the patellar tendon into the tibial tubercle.

B. *Incisions Which Divide the Patella* (These incisions have been largely discarded in favor of parapatellar incisions.)

1. Vertical division of the patella (Brackett and Hall, Jones).

a. *Indications:*
(1) Exploration of the anterior portion of the joint;
(2) Osteochondritis dissecans;
(3) Removal of joint mice.

b. *Position of the patient:* The patient is supine with the knee supported in about 60 degrees of flexion.

c. *Landmarks:* (The same landmarks are used in all methods of dividing the patella.)
(1) Quadriceps tendon;
(2) Patella;
(3) Patellar tendon;
(4) Tibial tubercle.

d. *Incision:* A curvilinear incision is made, following the obtuse angle formed by the quadriceps, the patella, and the patellar tendon. It is begun about three inches above the upper border of the patella. The quadriceps tendon, the patella, and the patellar tendon are divided longitudinally at the junction of their inner and middle thirds, the latter structure being sectioned to the level of its insertion into the tibial tubercle. This method allows displacement of the inner third of the bone to the inner side of the joint, and thereby gives wider exposure of the medial condyle of the femur. The patella is either split with an osteotome or sectioned with a saw. The parts exposed are the quadriceps pouch, the anterior part of the condyles of the femur, the anterior margins of

the semilunar cartilages, the anterior cruciate ligament, the insertion of the posterior cruciate, the infrapatellar fat pad, and the ligamentum mucosum.

2. Transverse sectioning of the patella, as advocated by von Volkmann, should be mentioned only to be condemned. The results following this procedure have been unsatisfactory, with permanent limitation of flexion of the knee.

3. Sagittal division of the patella is described by Devine in a well-illustrated article. He describes his operation in the following manner:

a. A curved incision is made, the middle of which is about one-half an inch below the lower margin of the patella. The flap of skin and fat is dissected upward and laterally until the quadriceps tendon, the anterior surface of the patella, and the patellar tendon are exposed.

b. With a butcher's saw, a cut is made, starting in the quadriceps tendon about one-half an inch above the upper margin of the patella, in a direction sloping backward through the tendon of the quadriceps, the patella, and the patellar tendon, and coming out of the latter on the posterior surface, one-half inch below the lower margin of the patella. This divides the patella into the anterior and posterior halves without disturbing its cartilaginous surfaces.

c. The assistant bends the knee; the patellar fragments are separated; and the lateral expansion of the joint is stretched tightly. The surgeon places a small hook under the lower margin of the upper fragment, turns its cartilaginous surface over; and, as the knee bends, he divides the fibers of the lateral expansions of the vasti muscles.

d. When the joint is closed, the fragments of the patella fall nicely into position and are sutured together with the quadriceps tendon. The synovial membrane and the quadriceps expansions are closed separately. The writers have not used this method.

4. Bougot and De La Rue describe two methods of approach by division of the patella; one is a vertical incision for lesions of the femur, which is similar to the ordinary split-patella incision, and the other is an oblique incision where the patella is divided obliquely from front to back for lesions involving the tibia. This oblique division of the patella, used in place of the vertical division, gives a good exposure of the articular cartilages, the ligaments, and the upper end of the tibia.

C. *Incisions Which Divide the Tendon of the Quadriceps Muscle*

1. Plastic division of the tendon of the quadriceps (Putti, Campbell).
   a. *Indications:*
      (1) Arthroplasty of the knee.
   b. *Position of the patient:* The patient is supine with the knee flexed to from 25 to 30 degrees.
   c. *Landmarks:*
      (1) Condyles of the femur;
      (2) Condyles of the tibia;
      (3) Quadriceps tendon;
      (4) Patella.
   d. *Incision:* The incision in the skin, in the form of an inverted U, is begun over the medial condyle of the tibia, anterior to the tibial collateral ligament. It is carried proximally to a point one inch above the patella, then curved laterally across the quadriceps tendon, and continued distally along the anterior margin of the fibular collateral ligament to end over the lateral condyle of the tibia. The fascia, aponeurosis, and synovia are divided in the line of the skin incision. The quadriceps tendon is sectioned transversely just above the upper margin of the patella, or it is divided by a Z plastic incision. If the quadriceps tendon is to be lengthened, this may be facilitated by a longitudinal incision over the quadriceps tendon, extending upward from the apex of the U. Putti used this approach but discontinued its use, since occasionally the skin margins were found to slough at the junction of the longitudinal limb with the U (Campbell).

2. Plastic division of the tendon of the quadriceps (Coonse and Adams).
   a. *Indications:*
      (1) Complete exploration of the joint;
      (2) Synovectomy;
      (3) Arthroplasty;
      (4) Treatment of fractures of the lower end of the femur.
   b. *Position of the patient:* The position of the patient is the same as for the parapatellar approach.
   c. *Landmarks:*
      (1) Condyles of the femur;
      (2) Quadriceps;
      (3) Patella.

d. *Incision:* The quadriceps tendon, the patella, the infrapatellar tendon, and the aponeurosis of the vastus medialis are exposed by a curved medial parapatellar incision. An inverted Y-shaped incision is made in the quadriceps tendon and aponeurosis of the vasti muscles (Fig. 11). The stem of the Y lies over the quadriceps and the two prongs extend on either side of the patella. The patella is then turned downward with exposure of the joint. Upon closure of the divided quadriceps tendon and aponeurosis, the knee can be bent to a right angle without undue tension, if sutures of sufficient strength are used. The writers have had but one experience with this operation. A good exposure to the anterior compartment of the knee joint was obtained.

D. *Incisions Which Divide the Tendon of the Patella Transversely*

1. The U-shaped incision with division of the patellar tendon (Textor).
   a. *Indications:*
      (1) Excision of the knee in extensive destruction of the joint from disease or injury;
      (2) Drainage of badly infected joints in cases of compound fractures.
   b. *Position of the patient:* The position of the patient is the same as that for parapatellar incisions.
   c. *Landmarks:*
      (1) Condyles of the femur;
      (2) Patella;
      (3) Patellar tendon;
      (4) Tubercle of the tibia.

d. *Incision:* The skin incision is started over the prominent part of the medial femoral condyle just below the insertion of the tendon of the adductor magnus. From here it is continued downward in a gentle curve to pass just below the insertion of the patellar tendon into the tibial tubercle, and then upward and outward to the most prominent part of the lateral condyle of the femur. The incision should form a broad base which extends between the condyles of the femur. The margins of the skin are reflected sufficiently to permit division of the patellar tendon and the aponeurotic expansions of the vasti muscles. The anterior margins of the tibial collateral ligament on the medial side and the iliotibial tract on the outer side are identified and preserved. The entire flap of skin and aponeurosis, with a broad base extending between the femoral condyles, is turned upward. With flexion of the knee the following structures are exposed:

(1) Upper end of the tibia;
(2) Lower end of the femur;
(3) Quadriceps pouch;
(4) Semilunar cartilages;
(5) The patella and the cruciate and collateral ligaments.

Excision of bone and soft tissues can be carried out as indicated in individual cases. To allow drainage in clean cases of excision of the knee, the wound is closed with inter-

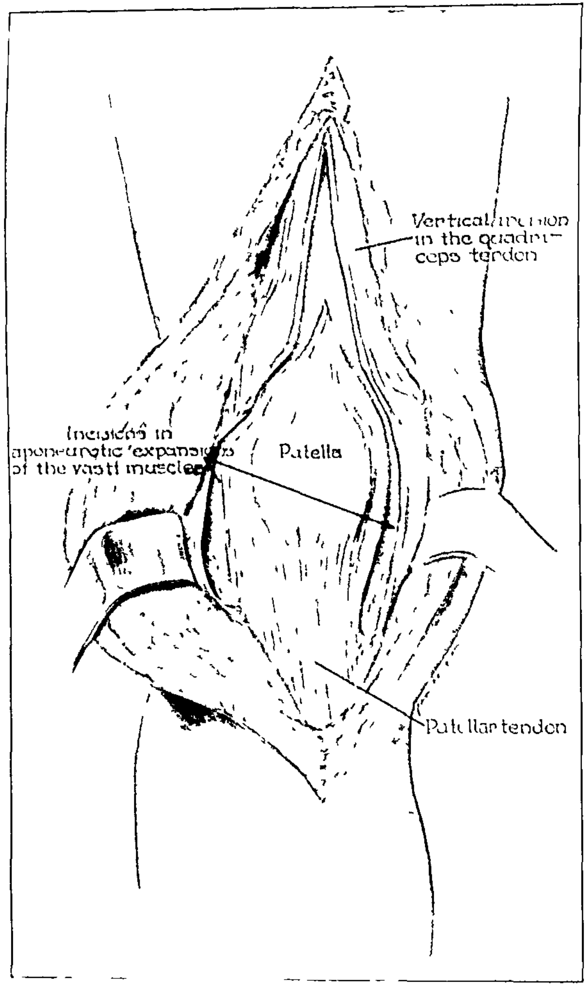


FIG. 11
Division of the quadriceps tendon after the method of Coonse and Adams.

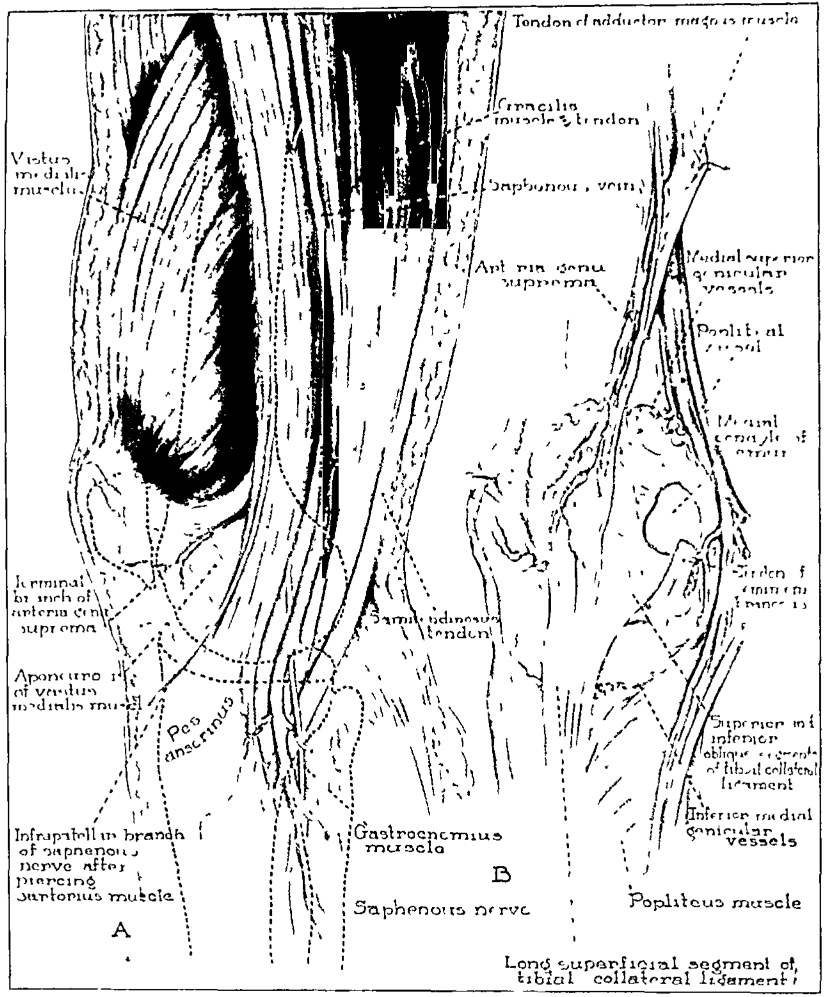


FIG 12
Anatomical dissections of the medial aspect of the knee, showing the saphenous nerve, the saphenous vein, and the sartorius muscle.

rupted sutures only to the deep fascia and the skin. As a last recourse in severely septic joints, the patellar tendon is stitched to the skin on the anterior surface of the thigh at the junction of its upper and middle thirds.

2. The H-shaped incision of Ollier.

a. *Indications:* Ollier used this incision for excision of the knee in cases of extensive destruction of the joint. In addition, he employed posterolateral and posteromedial incisions for counter-drainage.

b. *Incision:* A transverse incision in the skin is made just below the patella, preferably with the knee in the position of 90 degrees of flexion. This incision must stay within the limits of the anterior borders of the collateral ligaments. From each end of the transverse incision, a vertical incision is made, nine centimeters in length, seven of which lie above the transverse incision. The joint is entered by cutting the patellar tendon. Counter-incisions lie anterior to the biceps tendon on the outside and to the sartorius and gracilis tendons on the medial side of the joint. The writers do not advocate the use of this incision.

II. *Approaches to the Medial Aspect of the Knee Joint*

Surgical Anatomy: The important structures on the medial aspect of the knee joint are: (1) the tibial collateral ligament, (2) the internal intermuscular septum, (3) the tendons of the sartorius, gracilis, and semitendinosus, (4) the bursae in relation to the tibial collateral ligament, (5) the saphenous vein, the saphenous nerve, the saphenous branch of the arteria genus suprema, and (6) the two branches of the medial femoral cutaneous nerves (Fig. 12, *A*).

The tibial collateral ligament is a far more extensive structure than usually described in texts on anatomy or surgery. It may be divided into four segments. The anterior superficial portion is the part which extends as a flat band, approximately four inches in length and one-half an inch in width, and is attached to the ovoid area in the region of the medial epicondyle of the femur. The distal attachment is almost one inch in length on the medial surface of the tibia, and lies about one and one-half inches below the line of the knee joint. The deep anterior portion of the ligament lies beneath the superficial part with which it is intimately blended. It consists of short fibers which bridge the joint from the femoral epicondyle to the area just below the margin of the inner condyle of the tibia. The posterosuperior, oblique portion extends from the posterior part of the femoral attachment downward and backward to the margin of the tibial condyle. The tibial attachment is extensive, and reaches to the posterior limit of the condylar margin. This part gives additional anchorage to the semilunar cartilage. The posterosuperior and posteroinferior, oblique portions of the ligament blend with the posteromedial portion of the joint capsule, forming a hemispherical pouch. This pouch is lax in flexion of the knee, but in extension it becomes tense as it encloses the posterior part of the medial femoral condyle. The existence of this arrangement should be especially emphasized. Grasping in full extension the prominent posterior part of the medial femoral condyle in an accurately fitting half bucket, it is a major factor in stabilizing the knee in this position (Fig. 12, *B*).

The intermuscular septum on the medial aspect of the thigh extends from the fascia lata inward to be attached to the linea aspera. It blends intimately with the tendon of the adductor magnus which inserts into the adductor tubercle of the femur. This membrane separates the vastus medialis in front from the adductor magnus and adductor longus behind. It forms the line of separation between the popliteal space and the anterior compartment of the knee. The tendons of the sartorius, gracilis, and semitendinosus embrace the posteromedial aspect of the medial femoral condyle, and, as they pass to their insertions in the proximal part of the anteromedial surface of the upper part of the tibia, they are separated from each other by a bursa. The tendon of the sartorius lies superficial and anterior to the tendons of the gracilis and semitendinosus, while all three span the inferior

portion of the tibial collateral ligament. The internal saphenous vein passes across the posterior part of the medial aspect of the knee, lying upon the tendon and muscle belly of the sartorius. The medial cutaneous nerve of the thigh, a branch of the femoral nerve, is found in two branches in this region The anterior branch crosses the sartorius muscle and makes its appearance through the fascia lata in the distal part of the thigh, a short distance in front of the great saphenous vein. The posterior branch runs distally along the posterior border of the sartorius, pierces the deep fascia on the medial side of the knee, and comes to rest behind this muscle and the saphenous nerve. The saphenous nerve is the longest branch of the femoral nerve. It emerges from the lower end of Hunter's canal by passing beneath the fibrous expansion which stretches between the vastus medialis and the adductor muscles. It is accompanied by the saphenous branch of the arteria genus suprema As it emerges from under cover of the sartorius muscle, it penetrates the deep fascia and gives off its infrapatellar branch, which pierces the sartorius and appears on the surface of the fascia lata on the medial part of the knee Here it can be rolled over the anteromedial surface of the tibia about one-third of an inch below the joint line.

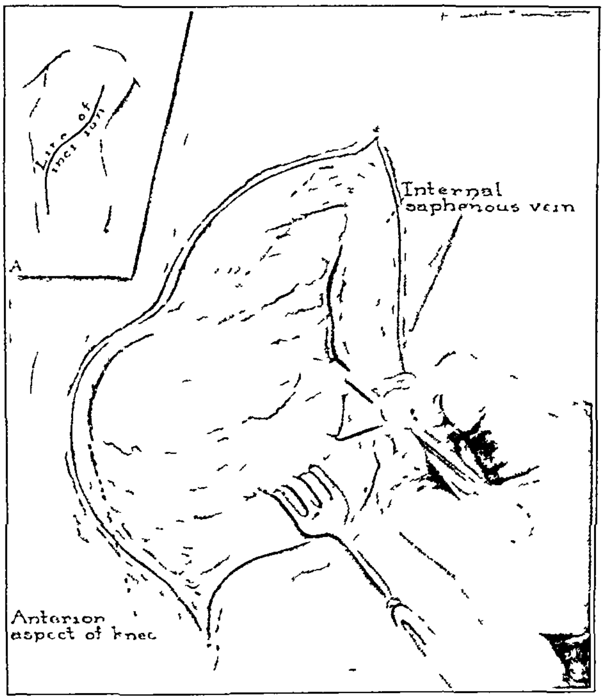


FIG. 13
The S-shaped incision on the medial aspect of the knee.

In this region the superomedial and inferomedial genicular vessels pass forward on the femur and the tibia deep to the tibial collateral ligament to join in the anastomosis formed about the anterior surface of the knee joint

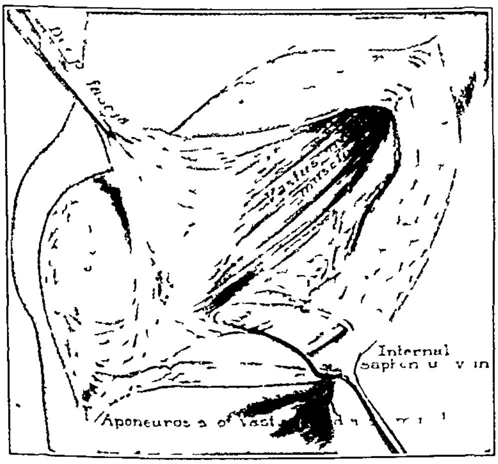


FIG. 14
The S-shaped incision with reflection of the fascia lata.

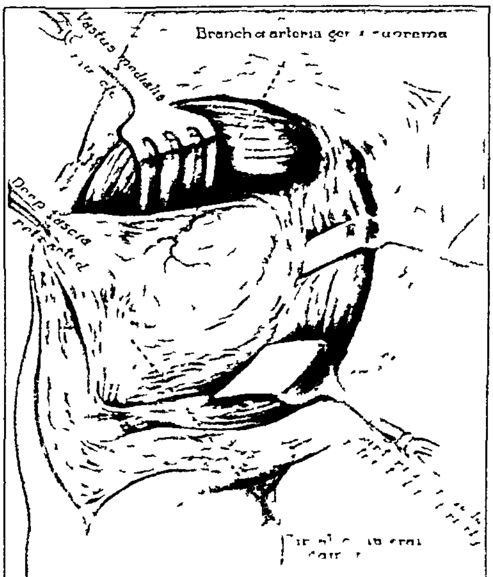


FIG. 15
The S-shaped incision with retraction of the muscles and exposure of tibial collateral ligament.

A. *The S-Shaped Incision*

1. *Indications:*
   a. Rupture of the tibial collateral ligament, especially when accompanied by injury to the anterior cruciate ligament and the internal semilunar cartilage (medial meniscus).
   b. Repair of neglected tears of the tibial collateral ligament, which requires the use of the medial hamstring tendons.
2. *Position of the patient:* The knee is supported on a narrow sandbag well above the level of the opposite leg in a position of from 15 to 20 degrees of flexion and in slight external rotation.
3. *Landmarks:*
   a. Adductor tubercle of the femur;
   b. Medial hamstring muscles;
   c. Condyle of the tibia;
   d. Joint line;
   e. Tibial tubercle.

4. *Incision:* A curvilinear incision of the skin and subcutaneous tissue is made, beginning two inches above the adductor tubercle on the posteromedial aspect of the joint, directly over the tendons of the sartorius and gracilis. It follows the course of these tendons to the level of the joint, where it is then curved gently forward along its margin to the anterior border of the upper end of the tibia. Here it is turned downward again to end just below the tibial tubercle. The skin and subcutaneous tissue are reflected upward and downward from the surface of the deep fascia (Fig. 13). The deep fascia is then incised in a vertical direction from the adductor tubercle to the medial surface of the upper end of the tibia (Fig. 14). The structures which are identified are the insertion of the adductor magnus into the adductor tubercle, and the long superficial segment of the tibial collateral ligament passing to the medial surface of the upper end of the tibia (Fig. 15). The tendons of the sartorius, gracilis, and semitendinosus are reflected posteriorly to expose the oblique segments of the tibial collateral ligament and the tendinous insertion of the semimembranosus into the posterosuperior aspect of the upper end of the tibia. Posterior to the sartorius muscle, the saphenous nerve and the posterior division of the medial femoral cutaneous nerve are seen. Inferiorly, the infrapatellar branch of the saphenous nerve passes through the sartorius, and lies on the deep fascia one-fourth of an inch below the medial margin of the tibia.

Anterior to the long superficial segment of the tibial collateral ligament, the aponeurosis and synovial membrane are incised to expose the anterior compartment of the joint. The anterior cruciate ligament and the anterior portion of the semilunar cartilage (medial meniscus) are then identified. An incision is made through the oblique segments of the tibial collateral ligament to expose the posterior extremity of the internal semilunar cartilage (medial meniscus). In late operations for the repair of the tibial collateral ligament, particularly where its posterior oblique segments have been torn, or where the tendons of the gracilis or semitendinosus are to be used to reinforce the inner aspect of the joint, the sartorius muscle is retracted anteriorly, instead of posteriorly (Fig. 16). This makes it imperative to identify the saphenous nerve and its infrapatellar branch. Unless the dissection is carried deep to the fascia lata, it is best to expose the saphenous vein, which is generally accompanied by the anterior branch of the medial cutaneous nerve of the thigh.

Structures which are made accessible by this curved incision are all parts of the tibial collateral ligament, the medial hamstring muscles, including the sartorius and gracilis, the entire internal semilunar cartilage (medial meniscus), the anterior cruciate ligament, the infrapatellar fat pad, and the medial margin of the ligamentum mucosum.

The wound is closed with interrupted sutures to the deep fascia, to the fibrous aponeurosis, and to the skin.

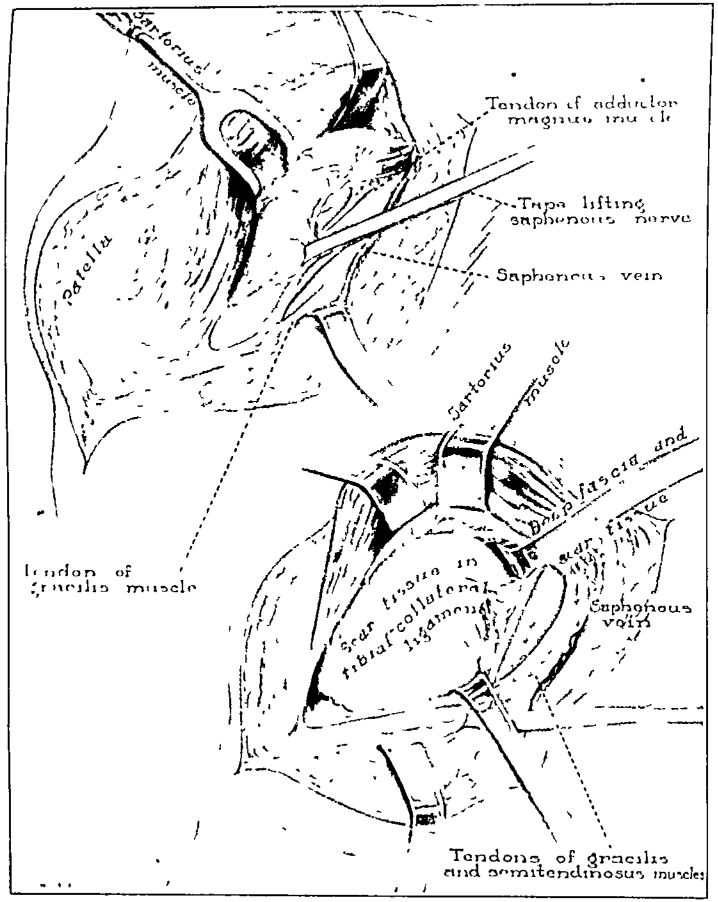


Fig. 16
The medial approach, showing an old tear of the tibial collateral ligament. In this case the sartorius was retracted anteriorly, rather than posteriorly, after exposure of the saphenous vein and the saphenous nerve.

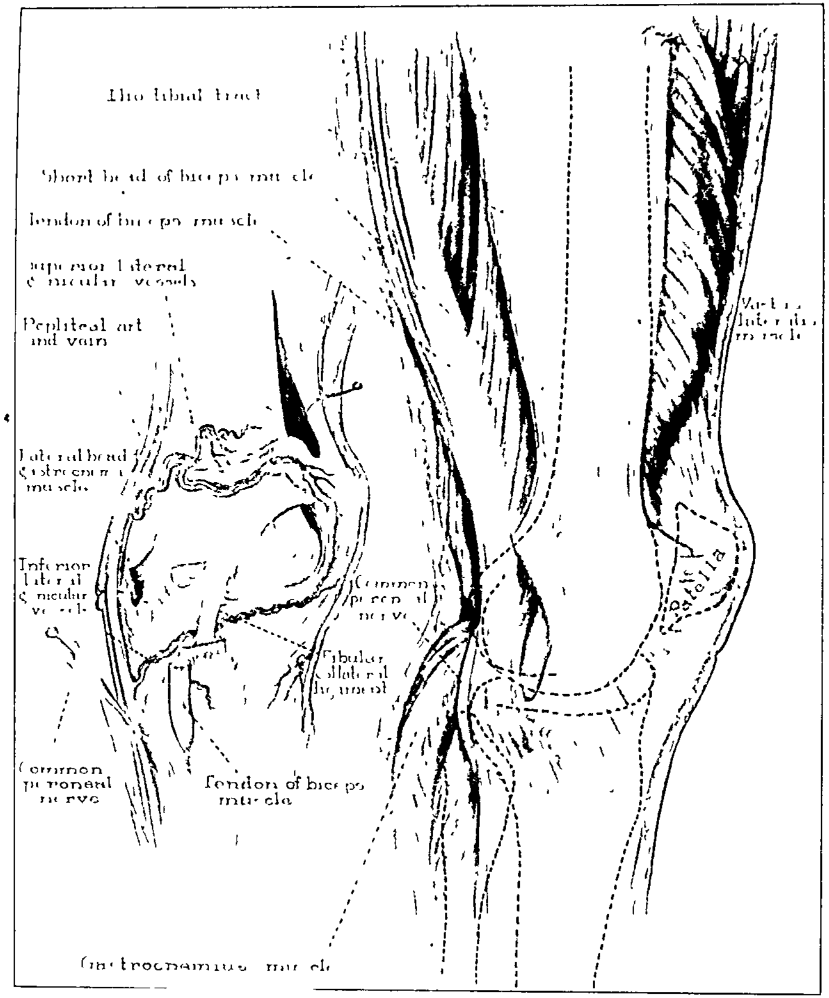


Fig. 17
Anatomical dissections of the lateral aspect of the knee.

B. *The Straight or Curved Incision*

1. A straight or simple curved incision made in a downward direction from the adductor tubercle may be used, if a more limited exposure is sufficient.

III. *Approaches to the Lateral Aspect of the Knee Joint*

Surgical Anatomy: The important structures on this aspect of the joint are, from before backward, the iliotibial tract, the lateral intermuscular septum, the fibular collateral ligament, the tendon of insertion of the popliteus muscle, the tendon of insertion of the biceps, and the common peroneal nerve (Fig. 17).

The iliotibial tract is in reality the fibrous tendon of the tensor fasciae femoris, which embraces the lateral condyle of the femur (Saunders), and is inserted into the upper margin of the external tuberosity of the tibia. The lateral intermuscular septum passes inward from the tract to insert into the linea aspera. It separates the vastus lateralis muscle in front from the short head of the biceps muscle behind. As in the case of the medial intermuscular septum, it separates the anterior compartment of the knee and the popliteal space on the lateral aspect of the joint. The fibular collateral ligament is attached above to the lateral epicondyle of the femur and below to the head of the fibula. The tendon of the biceps muscle is inserted into the head of the fibula, dividing into two parts to enclose the ligament from which it is often separated by a bursa. Beneath the fibular collateral ligament, the tendon of the popliteus muscle is inserted into the lateral epicondyle of the femur. It is surrounded by a synovial sheath which is an extension of the synovial membrane of the knee joint. A short distance posterior to the fibular collateral ligament, a thick capsular segment passes from the head of the fibula to the condyle of the femur; this is sometimes termed the short fibular collateral or arcuate ligament. In this region the superior lateral genicular artery passes beneath the tendon of the biceps, pierces the lateral intermuscular septum above the femoral attachment of the fibular collateral ligament, and breaks up into branches which anastomose in the substance of the vastus lateralis. The inferolateral genicular artery passes outward on the fibular head of the soleus muscle, and then beneath the fibular collateral ligament, just above its insertion into the head of the fibula.

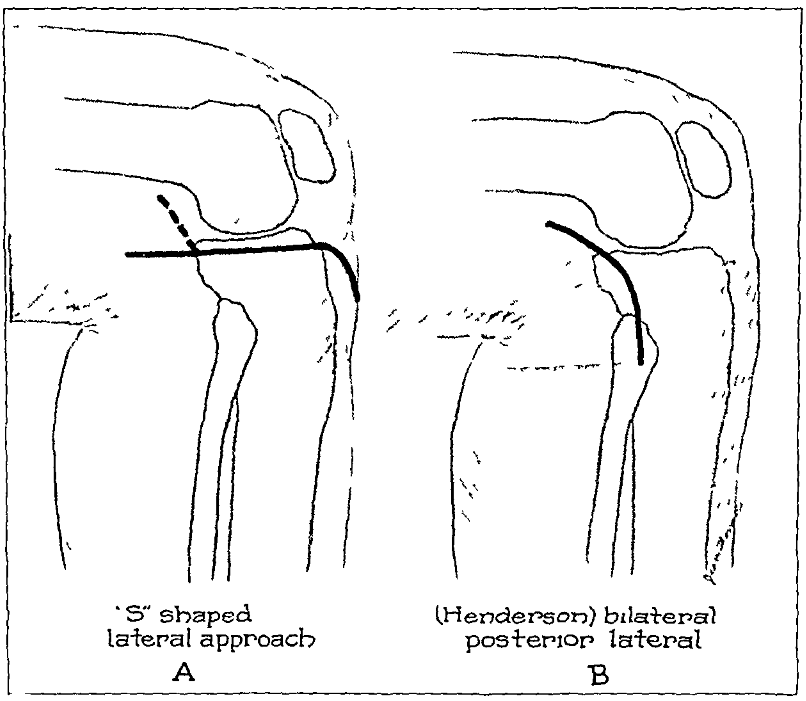


FIG. 18
Incisions on the lateral aspect of the knee.

A. *The S-Shaped Incision* (Fig. 18)

1. *Indications:*
   a. Derangements of the fibular collateral ligament;
   b. Open reduction of fractures of the lower end of the femur;
   c. Cysts of the external semilunar cartilage (lateral meniscus).
2. *Position of the patient:* The leg may be placed on a sandbag above the level of its fellow, or the knee may be flexed at right angles over the edge of the

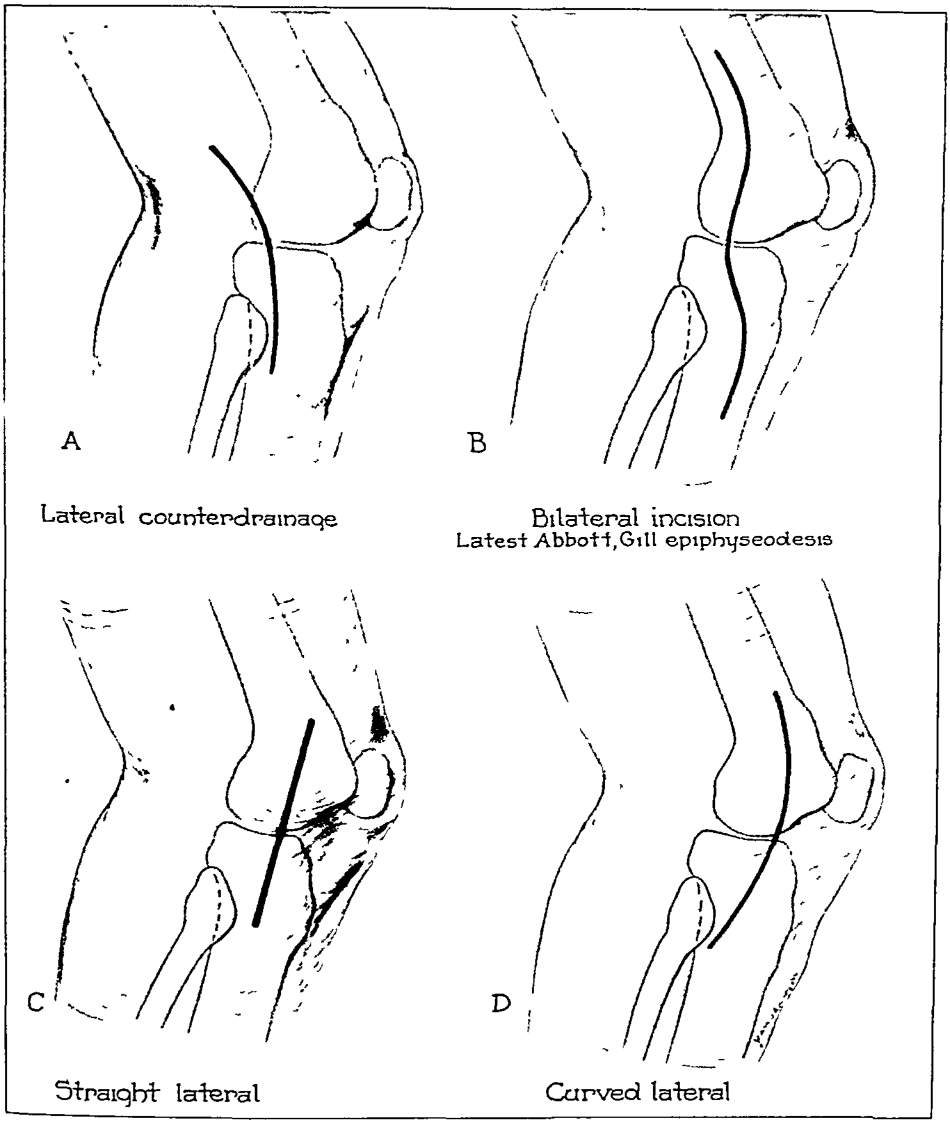


FIG. 19
Incisions on the lateral aspect of the knee.

table with the calf supported so that the posterolateral aspect of the knee is free. The writers prefer the Trendelenburg position, since its helps maintain the position of the patient.

3. *Landmarks:*
   a. Lateral condyle of the femur;
   b. Head of the fibula;
   c. Biceps tendon;
   d. Iliotibial band;
   e. Lateral aspect of the joint line;
   f. Patella;
   g. Infrapatellar tendon.

4. *Incision:* The incision is similar to the incision for complete exposure of the medial aspect of the joint. It is begun about two inches above the lateral condyle of the femur, lying well posteriorly in the sulcus between the tendon of the biceps muscle and the iliotibial tract. It is continued directly forward, following the lateral margin of the upper

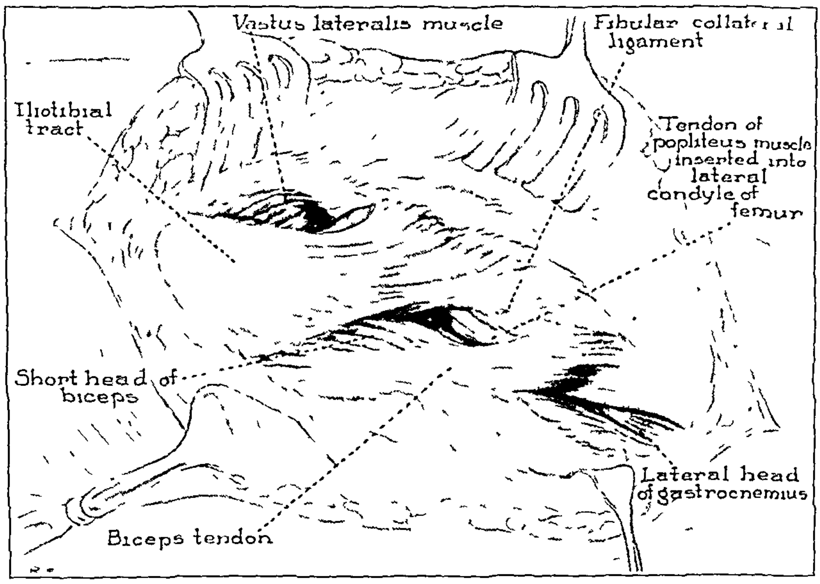


FIG. 20
The structures which are exposed through the curved lateral incision.

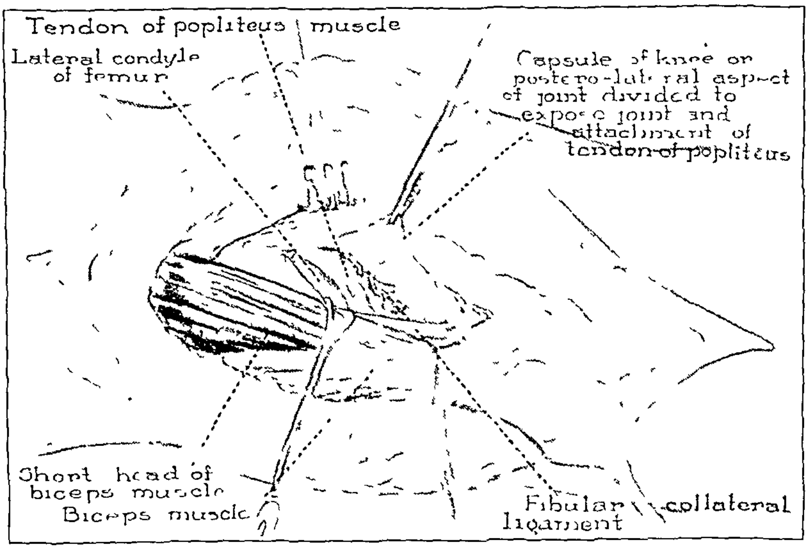


FIG. 21
The curved lateral incision with exposure of the deep structures and the insertion of the tendon of the popliteus muscle.

end of the tibia, and is then curved downward to the tibial tubercle. The structures exposed are the biceps tendon, the posterolateral part of the joint capsule, the fibular collateral ligament, and the lower part of the iliotibial tract (Fig. 20). The peroneal nerve is found lying just behind the biceps tendon. From here it can be traced to the lateral aspect of the neck of the fibula. The biceps tendon is followed to its insertion into the fibula, where it will be found to bifurcate in order to enclose the fibular collateral ligament. At this stage, the ligament is followed upward to its attachment into the epicondyle of the femur. Lying deep and slightly posterior to the fibular collateral ligament, the tendon of the popliteus is exposed (Fig. 21). If the anterior aspect of the joint is to be entered, the anterior portion of the fibrous aponeurosis of the vastus lateralis and the synovial membrane are excised in a direction downward and forward. The anterior half of the external *semilunar cartilage* (lateral meniscus) is readily exposed without division of the tendinous fibers of the iliotibial tract. By this incision an excellent approach is obtained to the fibular collateral ligament, the biceps tendon, the common peroneal nerve, the posterior joint line, the iliotibial tract, the entire semilunar cartilage (lateral meniscus), the lateral aspect of the fat pad, and the infrapatellar tendon.

B. *The Straight or Curved Incision* (Fig. 19)

As in the case of the medial aspect of the knee, a straight or curved incision may be employed for a limited exposure.

IV. *Exposure of the Semilunar Cartilages* (*the Menisci*)

Surgical Anatomy: On the anteromedial aspect a triangular space is formed, the boundaries of which are the patellar tendon in front, the condyle of the femur and the anterior margin of the tibial collateral ligament behind, and the upper margin of the tibia below. A similar space is formed on the anterolateral aspect of the knee joint, bounded in front by the patellar ligament, behind by the condyle of the femur and the fibular collateral ligament, and below by the margin of the tibia.

A. *For Partial Removal of the Internal Semilunar Cartilage* (*Medial Meniscus*)

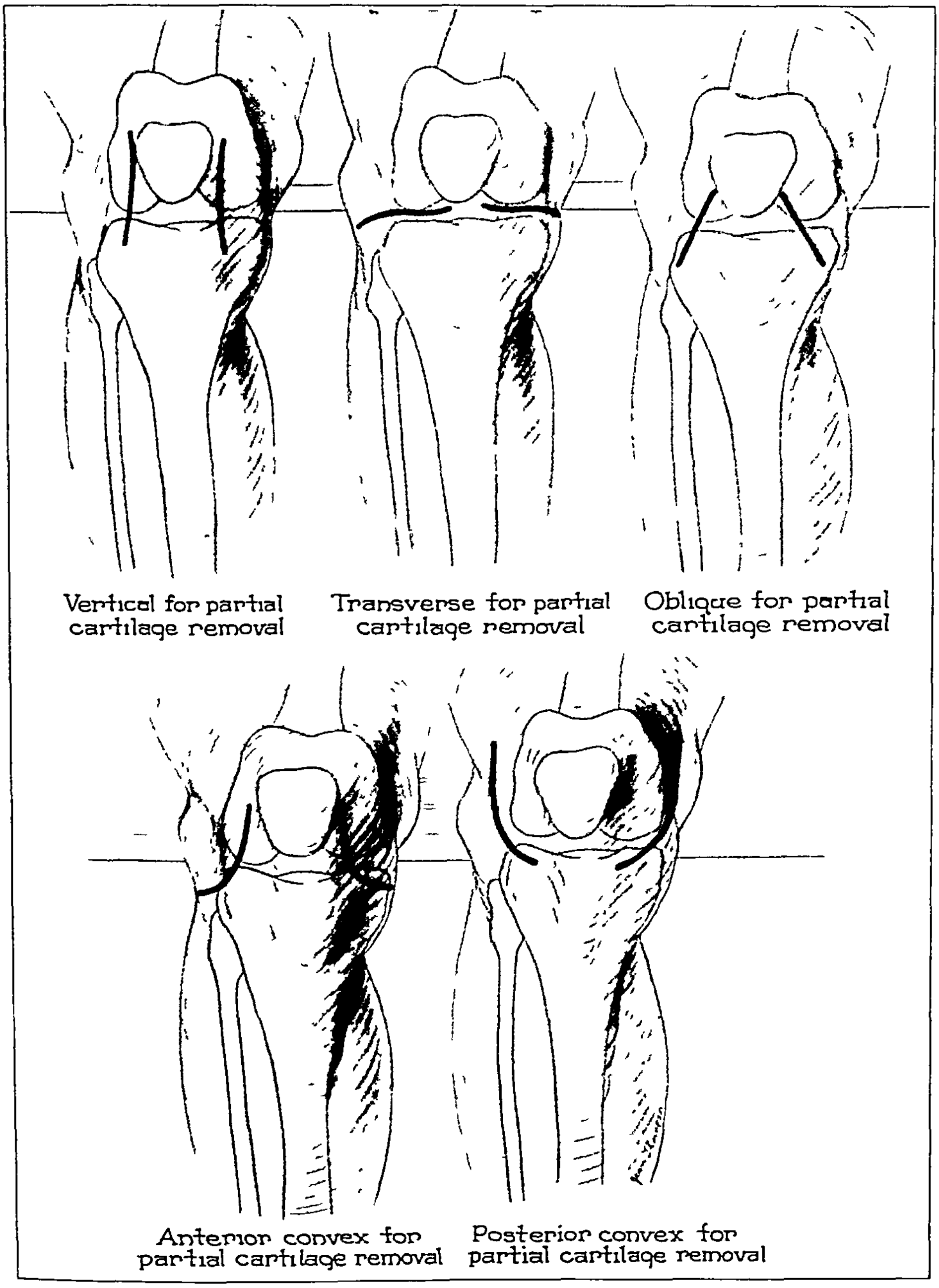


FIG. 22
The anterior incisions for partial removal of the semilunar cartilages.

1. *Position of the patient:* The patient is in a slightly Trendelenburg position, with the knee flexed to 90 degrees over the end of the table.
2. *Landmarks:*
   a. Medial condyle of the femur;
   b. Tibial tubercle;
   c. Patellar tendon;
   d. Patella;
   e. Anteromedial joint line.
3. *Incision:* The incisions which may be used for partial removal of the internal semilunar cartilage are the curved incision with an anterior convexity (Jones), the curved

incision with a posterior convexity (Fisher), the oblique or nearly transverse incision, and the vertical incision (Fig. 22). These incisions are made in order to expose the joint adequately, and they vary in their directions according to the decision of the operating surgeon. The structures which are exposed are the infrapatellar fat pad, the ligamentum mucosum, the anterior portion of the origin of the anterior cruciate ligament, and the anterior two-thirds of the semilunar cartilage (medial meniscus).

The curved skin incision, with an anterior convexity, is made on the anterior surface of the medial condyle of the femur, on a level with the lower portion of the patella. It is curved gently downward to the level of the tibia, and backward along its upper margin for a distance of three-quarters of an inch. In the subcutaneous tissue, the infrapatellar branch of the saphenous nerve is identified one-half an inch below the medial margin of the tibia. It is freed and retracted, with exposure of the aponeurosis of the vastus medialis. This aponeurosis and synovial membrane are incised, and the joint is entered.

B. *For Complete Removal of the Internal Semilunar Cartilage* (*Medial Meniscus*)

1. *Indications:*
   a. Derangements of the cartilage, especially when the posterior portion is damaged;
   b. Cysts of the semilunar cartilage;
   c. Limited exposure of the tibial collateral ligament.
2. *Position of the patient:* The patient is supine in a partial Trendelenburg position, with the knee flexed 90 degrees over the end of the table. The calf of the leg is supported from behind, to free completely the posteromedial aspect of the knee.
3. *Landmarks:*
   a. Medial condyle of the femur;
   b. Medial tibial tubercle;
   c. Patellar tendon;
   d. Patella;
   e. Anteromedial joint line.
4. *Incision:* The descriptions of the following incisions are taken from published articles by Cave, Bosworth, and Fisher (Fig. 23).

a. *The Cave incision:* The skin incision is begun three-eighths of an inch above and behind the internal femoral epicondyle. It is then curved downward to the joint line, and then forward one-quarter of an inch below the joint line to the patellar tendon. The flap formed of skin and subcutaneous tissue is dissected upward to expose the vastus aponeurotic expansion and the tibial collateral ligament. The anterior part of the joint capsule is incised just in front of the tibial collateral ligament, and the synovia is opened through the same incision. The posterior capsule of the joint is then opened behind the long superficial segment of the tibial collateral ligament. Therefore, two openings are made into the joint,—one in front of, and one behind the tibial collateral ligament. The accessible structures are the internal semilunar cartilage (medial meniscus) and the medial portion of the fat pad (Fig. 24).

Closure is effected by interrupted sutures to the fibrous aponeurosis and the fibrous capsule lying, respectively, in front of and behind the tibial collateral ligament.

b. *The incision of Bosworth:* An oblique incision, slanting upward and slightly backward, is made over the anteromedial aspect of the joint. The skin and subcutaneous tissues are reflected forward, and the capsule is opened by a vertical incision at the usual point anteriorly, in line with its fibers. The synovial membrane above the meniscus is opened between two pairs of forceps, care being taken not to cut the articular surface of the underlying femoral condyle. The small synovial pouch below the meniscus should be opened in a similar fashion. By means of curved scissors, one blade of which is placed

above and the other below the meniscus, the anterior end of the meniscus can be freed from the synovial membrane and the coronary ligaments. The knee is then flexed, and the skin and subcutaneous tissue are dissected backward to the collateral ligament, close to the capsule of the joint. This capsule is opened along the posterolateral margin of the femoral condyle behind the collateral ligament by a vertical incision in line with its fibers. The anterior portion of the meniscus is then passed backward under the collateral ligament, and its posterior third can be visualized extending into the back of the joint. The posterior third is freed as far as the posterior tibial spine. When the knee is straightened, the posterior incision will be found to close tightly. The anterior incision of the capsule is closed with a few interrupted sutures

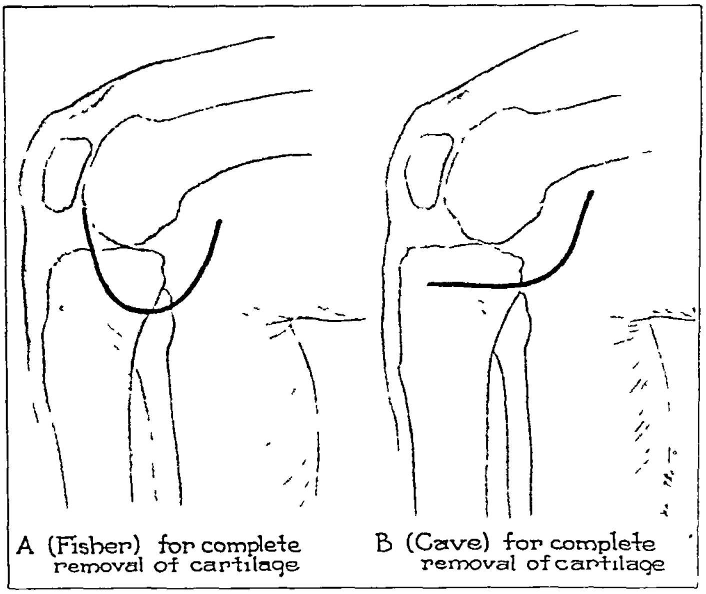


FIG 23
Two incisions for complete removal of the semilunar cartilages

In this approach the operating surgeon uses the extended and flexed positions of the knee, respectively, to facilitate exposure of the anteromedial and posteromedial portions of the joint.

c. *The incision of Fisher:* A curved incision is made over the anteromedial aspect of the joint. It is begun above at a point midway between the patellar ligament and the anterior border of the tibial collateral ligament at the level of the apex of the patella. It ends below and behind, slightly inferior to the internal margin of the upper part of the tibia at the anterior border of the tibial collateral ligament. The infrapatellar branch of the internal saphenous nerve should be identified and retracted. The capsule and synovial

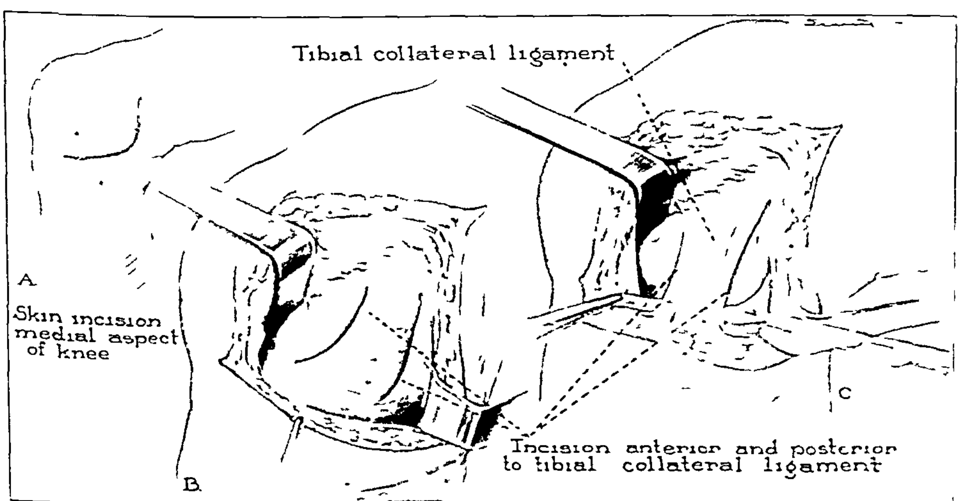


FIG 24
The Cave incision for removal of the internal semilunar cartilage (Redrawn from Cave)

membrane are next divided in line with the skin incision, but preferably a little nearer t the tibial collateral ligament, and the joint is thus opened. The semilunar cartilage i examined, and, if found necessary, the second portion of the incision is made as follows The anterolateral incision is temporarily closed with gauze, and the skin incision is contin ued over the inner margin of the joint slightly below the joint level; the incision is the carried upward and backward over the inner aspect of the posterior compartment of th joint. The completed incision is thus semicircular in outline, and enables a flap of ski and subcutaneous tissue to be raised. A curved incision is next made in that part of th capsule lying behind the tibial collateral ligament, and after the synovial lining is divided a good exposure of the posterior part of the joint and the posterior end of the semiluna cartilage is obtained.

Similar incisions are used for partial and complete exposure of the external semiluna cartilage (lateral meniscus).

V. *Bilateral Incisions*

Surgical Anatomy: The surgical landmarks on the lateral aspect of the joint, which ar utilized in all four of the bilateral incisions, are as follows:

1. Lateral epicondyle of the femur;
2. Head of the fibula;
3. Lateral margin of the upper part of the tibia;
4. Biceps tendon;
5. Lateral intermuscular septum;
6. Fibular collateral ligament;
7. Iliotibial tract.

On the medial aspect, the important landmarks are:

1. Adductor tubercle of the femur;
2. Tendons of the sartorius, gracilis, and semitendinosus;
3. Medial condyle of the femur;
4. Medial intermuscular septum;
5. Tibial collateral ligament.

On the lateral aspect of the knee, the lateral intermuscular septum and the fibular collatera ligament form the line of separation of the anterior compartment of the knee from th popliteal surface of the femur above and from the posterior compartment of the knee below. On the medial aspect of the knee, the medial intermuscular septum and the posterio margin of the tibial collateral ligament separate the anterior compartment of the joint from the popliteal surface of the femur and the posterior compartment of the knee.

A. *Exposure of the Popliteal Face of the Femur (Henry)*

1. *Medial Approach*

a. *Position of the patient:* "Put a sand-bag three inches thick under the buttock on the sound side, as he lies recumbent. Place the foot of the affected limb upon the opposite shin, as near the knee as possible."

b. *Incision:* "Make a longitudinal 8-inch cut which follows the bend of the limb, through skin and superficial fascia only, so that two inches of the cut lie distal to the adductor tubercle and six inches are proximal to it. Dissect back the lower lip of the wound for about an inch. Expose the sartorius just proximal to the level of the adductor tubercle, and free the muscle by dividing the deep fascia along its anterior edge. To do this, slip one blade of the blunt-nosed scissors under the fascia, and thus avoid injuring the synovial membrane of the knee, which is subjacent to the sartorius when the joint is flexed.

"The free sartorius falls back and exposes the tendon of the adductor magnus. The saphenous nerve leaves Hunter's canal in front of the tendon, and travels in this region deep to the sartorius. Sometimes the muscle carries the nerve with it upon its deep aspect; sometimes the nerve is left like a lax string across the bend of the limb. It is accompanied by a superficial branch of the anastomotica magna [arteria genus suprema, B.N.A.], some twigs of which may require division. The internal saphenous vein lies superficial to the sartorius, and is not seen if the skin incision has been properly placed.

"Pick up the thin fascia immediately behind the adductor tendon. Open it as one does the peritoneum. Thrust in the forefinger, keeping its back against the tendon till the nail strikes the bone at the middle of its

popliteal face. The popliteal vessels lie at some distance—often an inch—behind this surface; bend the forefinger and gently hook them up. Work the finger along the bone and mobilize the vessels—proximally as far as the opening in the adductor magnus, and distally to the notch between the condyles of the femur. An assistant protects the vessels with a wide retractor, and draws them back with the sartorius. He draws forward the adductor tendon and the part of the vastus muscle which arises from it.

"As the popliteal vessels are drawn back, the inconstant twigs which they send to the bone appear like strings across the wound; they are easily caught and divided, and the popliteal face of the femur is laid bare.

"The internal and external popliteal nerves [the tibial and common peroneal, B.N.A.] are not seen; they lie in that part of the wound which is next to the table, and are sufficiently remote from the bone to be out of harm's way."

2. *Lateral Approach*

a. *Position of the patient:* "The patient lies on the sound side with the sound limb extended. Place the knee of the affected side just in front of the other knee, so that the heel on the affected side rests upon the other shin: this tilts the popliteal surface to a convenient angle."

b. *Incision:* "Make a longitudinal 6-inch cut, through skin and superficial fascia only, along the hinder edge of the iliotibial tract two finger-breadths in front of the biceps tendon. The incision follows the bend of the limb and ends at the head of the fibula. Pick up the deep fascia immediately behind the iliotibial tract; divide it in the line of the skin incision, using blunt-nosed scissors to avoid injuring the synovia of the knee. At a point just proximal to the condyle, pass the index finger into the plane of cleavage between the biceps belly and the intermuscular septum. Work the finger up along the septum, and gently separate the few and slender fleshy attachments of the biceps from its posterior face. As this is done, the finger will meet with two or three resistant strands—posterior branches which the perforating vessels give off before they pierce the intermuscular septum. Divide and tie these branches. Then, keeping the back of the forefinger against the edge of the iliotibial tract, pass it into the popliteal fossa until the finger-tip touches the bone at the middle of the popliteal face. Gently hook up the popliteal vessels and mobilize them with the finger. Retract them back, together with the posterior wall of the wound.

"The popliteal aspect of the bone is now completely exposed. The two great nerves of the space—the internal and external popliteal [tibial and common peroneal, B.N.A.]—are not usually seen unless they are sought. They lie on a plane slightly behind that of the vessels, and the short head of the biceps shelters them as they skirt its medial edge."

B. *The Approach for Epiphyseodesis*

Position of the patient: The knee is held by sandbags in about 30 degrees of flexion, since this position relaxes the hamstring muscles, and the bony landmarks can be readily palpated. If the lower femoral and the upper tibial epiphyses are to be fused at one operation, they are exposed through long, curved incisions over the internal and the external aspects of the knee joint. If either the lower femoral or the upper tibial epiphysis is to be fused alone, then the upper or lower halves respectively of the incisions are employed.

1. Lateral aspect of the knee: The incision in the skin begins about two and one-half inches above the lateral condyle of the femur, directly over the interval between the biceps tendon and the tractus iliotibialis. It curves downward and backward to the head of the fibula, and then gently forward on the lateral surface of the upper part of the tibia. The lateral intermuscular septum is exposed in the upper part of the wound, and traced to its attachment to the linea aspera; this frees some of the fibers of origin of the vastus lateralis from its anterior surface. The muscle is retracted forward to expose the lateral surface of the femur and its junction with the lateral condyle. This junction marks the site of the epiphyseal cartilage. Immediately below, the capsule of the knee joint should be identified. The superolateral genicular vessels appear directly on the bone, passing forward after piercing the septum, and are distributed to the fibers of the vastus lateralis. For good exposure of the epiphyseal line of the femur, they may require ligation.

The exposure of the upper fibular and tibial epiphyseal cartilages is rendered safe by dissection of the common peroneal nerve. This structure is found by incision of the deep fascia, directly posterior and internal to the tendon of the biceps muscle. From here it can be traced downward, freed at the neck of the fibula, and retracted posteriorly. An incision over the upper and medial portions of the head of the fibula readily exposes its epiphyseal cartilage. The cartilage plate of the tibia is revealed by downward reflection, with a periosteal elevator, of the upper fibers of origin of the extensor muscles from the

arcuate line. The line of cartilage is shown by the removal of a thin section of bone one half to three-fourths of an inch (1.3 to 1.9 centimeters) below the margin of the joint.

2. Medial aspect of the knee joint

a. *Incision:* An incision, five inches in length, is made with its center approximately at the level of the adductor tubercle. In its upper part, it passes over the inner surface of the internal condyle of the femur; and in the lower part, it curves gently forward to follow the anterior margin of the tendon of the sartorius. By incision of the deep fascia, the anterior surface of the internal intermuscular septum is identified and traced to its attachment to the linea aspera. The vastus medialis, after separation of a few fibers of origin from the septum, is retracted anteriorly, exposing an interval, the floor of which is the internal surface of the femur and its junction with the flare of the adductor tubercle. The anterior and posterior walls of this space are formed, respectively, by the vastus medialis muscle and the tendinous portion of the adductor magnus. In the distal portion of this space lies the epiphyseal cartilage, overlapped by the attachment of the capsule and the reflected synovial membrane of the knee joint. The genicular vessels are ligated, and a vertical incision is made through the periosteum downward toward the epiphyseal cartilaginous plate. The periosteum, with the margin of joint capsule, is pushed downward laterally to expose the epiphyseal cartilage. This exposure is facilitated by raising a portion of cortical bone.

The upper tibial epiphysis is now exposed by incising the deep fascia along the anterior margin of the sartorius tendon. The infrapatellar branch of the saphenous nerve lies forward and need not be exposed. In the depth of the wound the anterior margin of the tibial collateral ligament is found and retracted backward. The epiphyseal cartilage is located directly in front of this ligament and from one-half to three-fourths of an inch below the upper margin of the tibia.

C. *The Posterolateral and Posteromedial Approaches* (*Henderson*)

Indications: Removal of loose bodies from the posterior compartment of the knee.

Position of the patient: The position of the patient is the same as that for the removal of the semilunar cartilages. The patient is placed in a modified Trendelenburg position, with the knee flexed to a right angle over the end of the table.

1. The posterolateral approach

a. *Incision:* A curved incision, from three and one-half to four inches in length, is made over the interval between the biceps tendon behind and the iliotibial tract in front. In the upper part of the interval, the external intermuscular septum is traced to the linea aspera, two inches above the lateral condyle of the femur. The lateral condyle of the femur is then exposed, with the origin of the fibular collateral ligament. Lying between the biceps tendon and the fibular collateral ligament, the tendon of the popliteus is identified. Beneath this tendon lies the lateral condyle of the femur, and, with the retraction of the tendon posteriorly, the posterolateral aspect of the knee-joint capsule is exposed. A vertical incision is made in the capsule, with exposure of the posterolateral aspect of the joint as far inward as the intercondylar notch.

2. The posteromedial approach

a. *Incision:* A curved incision with its convexity forward, three and one-half inches in length, begins at the adductor tubercle and is extended downward, following the course of the tibial collateral ligament. The structures identified after incision of the skin and subcutaneous tissues are the tibial collateral ligament and the sartorius muscle. With flexion of the knee, the sartorius is retracted posteriorly, and the oblique portion of the tibial collateral ligament is exposed and incised. The posteromedial compartment of the knee can be inspected laterally as far as the intercondylar notch.

D. *Posterior Capsulotomy in Flexion Contracture of the Knee Joint* (*Wilson*)

Position of the patient: The patient is supine, with the knee flexed from 20 to 30 degrees.

Incision: Vertical incisions are made on the posteromedial and posterolateral pects of the lower end of the femur. The hamstring tendons are lengthened, and the ntracted fascia is divided. A transverse incision is then made through the periosteum the posterior surface of the lower end of the femur, and this structure, together with the igin of the capsule, is freed from the femur. The flexion contracture of the joint is thus ieved.

. *Approaches to the Posterior Aspect of the Knee*

Surgical Anatomy: The popliteal fossa is a diamond-shaped space, which is bounded ove by the hamstring muscles and below by the converging heads of the gastrocnemius uscle. The roof of the fossa is covered by the popliteal fascia, which is a direct continua- on of the fascia lata. The popliteal fascia is pierced by certain structures which are im- rtant to the surgeon as landmarks. At the lower apex of the fossa, lying quite deeply tween the heads of the gastrocnemius muscle, is the posterior cutaneous nerve of the lf. After piercing the fascia, it passes upward within the fossa to become the uppermost anch of the posterior tibial nerve. As the first step in the dissection of the popliteal ssa, the posterior cutaneous nerve of the calf is identified, and serves thereafter as a guide rough the popliteal fat to the underlying posterior tibial nerve. The popliteal vessels lie iterior and medial to the posterior tibial nerve. Immediately lateral to the posterior taneous nerve of the calf is the external saphenous vein and the posterior cutaneous rve of the thigh. Two other nerve branches in this region which might confuse the rgeon are the lateral cutaneous nerve of the calf and the anastomotic peroneal nerve. hey arise as single branches or from a parent trunk from the common peroneal nerve and ss over the lateral head of the gastrocnemius under the fascia lata. The lateral cutane- is nerve supplies the skin on the anterolateral aspect of the proximal part of the leg, while e anastomotic peroneal branch proceeds downward to join the posterior cutaneous nerve the calf a short distance distal to the middle of the leg, forming the sural nerve. At the pper part of the fossa the common peroneal and posterior tibial nerves join to form the iatic nerve. The popliteal artery and vein with their genicular branches lie deep in the ssa, anterior and medial to the great nerve trunks (Fig. 25).

A. *The Mid-Line Approach to the Popliteal Space*

1. *Indications:*
   a. Exposure of the sciatic nerve and its branches;
   b. Neurectomy of the popliteal nerves in spastic paralysis;
   c. Aneurysm of the popliteal vessels;
   d. Flexion contracture of the knee with contracture of the hamstrings and posterior capsule of the knee joint;
   e. Removal of loose bodies in the posterior compartment of the knee;
   f. Rupture of the posterior cruciate ligament.
2. *Position of the patient:* The patient is placed in a prone position, with slight flexion of the knee. The lower extremity is supported on a narrow sandbag which raises it above the level of the opposite leg.
3. *Landmarks:*
   a. Hamstring tendons (internal and external) particularly the semitendinosus;
   b. Heads of the gastrocnemius;
   c. Head of the fibula.
4. *Incision:* One of two incisions may be employed, — vertical or curvilinear. he curvilinear incision is preferable, because it is less likely to form a keloid. In making his incision, the principal guide is the tendon of the semitendinosus muscle, which can be elt as a cordlike structure, passing obliquely downward and inward across the postero- nedial aspect of the joint. The incision is begun about three to four inches (7.5 to 10

centimeters) above the knee joint, follows the tendon of the semitendinosus downward t the level of the joint, turns laterally across its posterior aspect for a distance of about tw inches (5 centimeters), and is continued downward again over the lateral head of the gas trocnemius. The skin is reflected to expose the popliteal fascia.

The first structure to be identified is the posterior cutaneous nerve of the calf, as i lies beneath the fascia rather deeply between the two heads of the gastrocnemius (Fig. 26) It is accompanied by the cutaneous branch of the popliteal vein. Lateral to this nerve the external saphenous vein is also seen perforating the popliteal fascia to join the pop liteal vein at the middle of the fossa. Still farther laterally and again deep to the fascia the anastomotic peroneal nerve and the lateral cutaneous nerve of the calf are seen. Th posterior cutaneous nerve of the calf is the clue to the dissection. Traced proximally, i joins the posterior tibial nerve as its first branch. The location of the posterior tibia nerve, so readily found by this method, enables accurate dissection through the mass c fat which occupies the popliteal fossa. It is traced downward until one can see th branches to the heads of the gastrocnemius, the plantaris, and the soleus muscles. Thes branches are accompanied by arteries and veins and muscular branches from the poplitea vessels. The posterior tibial nerve is then followed proximally to the apex of the fossa where it joins the common peroneal nerve to form the sciatic. The common peronea nerve is dissected downward along the medial border of the biceps muscle and tendon, car being taken to preserve the lateral cutaneous nerve of the calf and the anastomotic branch As already stated, these two nerves may arise singly or from a common stem. The com mon peroneal nerve is followed to the head of the fibula, where it lies between the media border of the biceps and the lateral head of the gastrocnemius (Fig. 27). The poplitea artery and vein are now exposed, lying directly anterior and medial to the posterior tibia nerve. By gently retracting the artery and vein, the superolateral and superomedia genicular vessels can be readily found. Traced outward, these vessels pass just proxima to the heads of origin of the gastrocnemius, beneath the hamstring muscles on either side The next important step to facilitate wide exposure of the floor of the fossa is the section ing of the tendon of origin of the medial head of the gastrocnemius (Fig. 28). This tendi nous origin is freed from the femur and turned laterally to serve as a retractor for the popliteal vessels and nerves. Still greater access can be secured by ligation of one or more of the genicular vessels. If the posterolateral aspect of the joint is to be exposed, the lateral head of the gastrocnemius is dealt with in a similar fashion. With retraction of the larger vessels and nerves, the floor of the fossa is seen with the insertion of the semimembranosus into the tibia, and its fascial expansions to the oblique popliteal ligament, to the popliteal fascia, and to the tibial collateral ligament (Figs. 29 and 30).

The structures which are made accessible by the posterior mid-line approach are the posterior capsule of the knee joint, the posterior part of the semilunar cartilages (menisci), the posterior compartment of the knee, the posterior aspect of the condyles of the femur, the posterior aspect of the condyles of the tibia, and the origin of the posterior cruciate ligament.

The wound is closed by three layers of interrupted silk sutures to the capsule, to the deep fascia, and to the skin. The closure of the popliteal fascia is best effected by placing all sutures, and then drawing them taut and tying them one by one.

VII. *Approaches for Drainage of Sepsis of the Knee Joint*

Surgical Anatomy: The incisions which are used in sepsis of the knee joint are devised to drain the anterior compartment of the knee and the popliteal space. The structures which separate the anterior compartment and the popliteal space are the lateral and medial intermuscular septa, the fibular collateral ligament, and the tibial collateral ligament. If incisions are made to expose the anterior surface to the intermuscular septa, the anterior compartment of the joint is exposed. If the posterior surfaces of the septa are followed, the

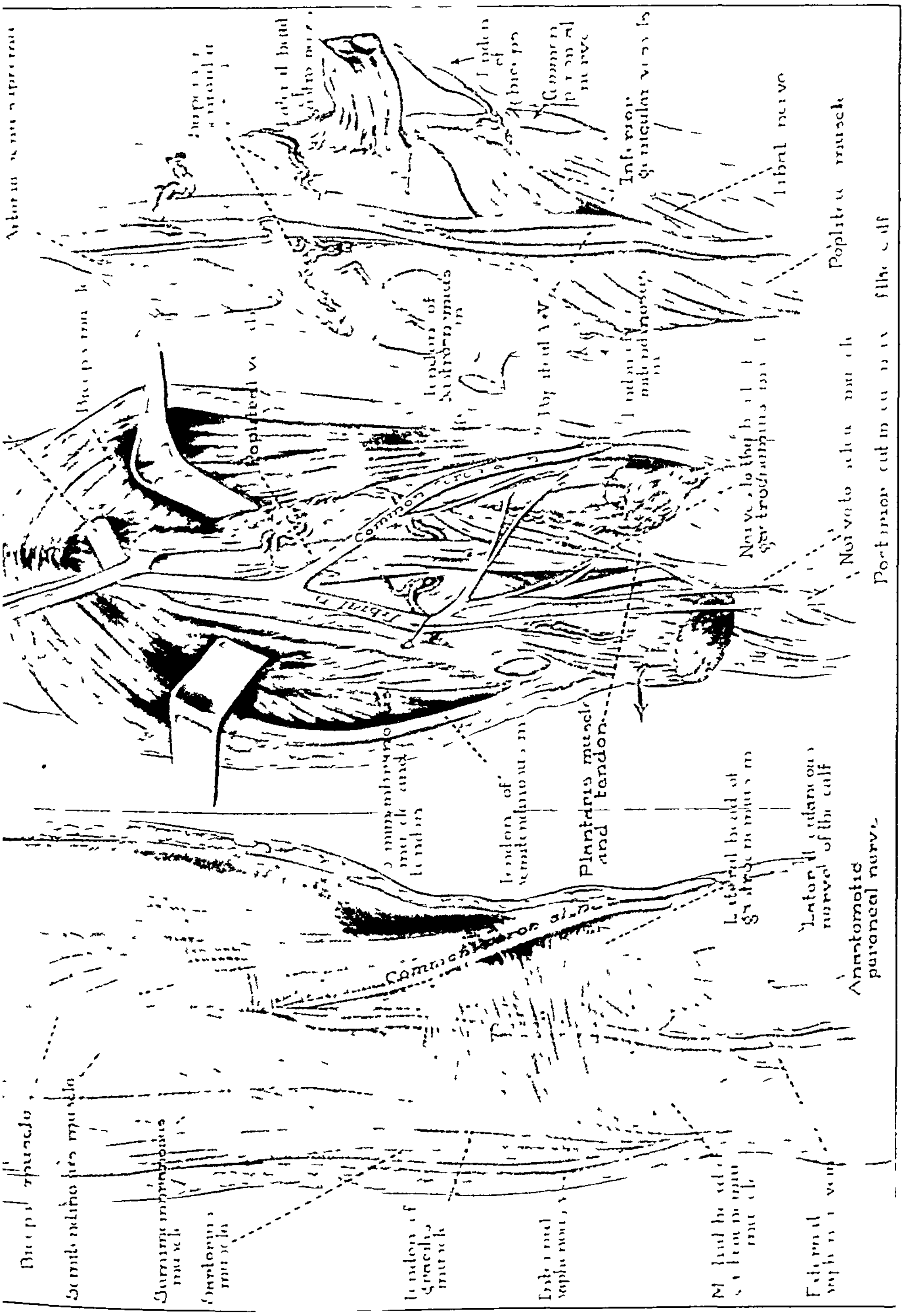


Fig. 25
An anatomical dissection of the posterior aspect of the knee.

popliteal space is entered. Incisions in front of the collateral ligaments expose the anterior part of the joint, while incisions posterior to the collateral ligaments enter the posterior compartment of the joint. In the popliteal space, there are certain fascial planes and bursae which are worthy of consideration from the viewpoint of the surgeon. The bursae between the semimembranosus and the medial head of the gastrocnemius frequently communicate with the knee joint. Consequently, incisions opening these bursae often lead directly into the joint. This is the rationale of the Klein approach on the posteromedial aspect of the joint. The popliteus tendon pierces the capsule of the joint, and a pouch of synovial membrane is prolonged on the anterior surface of the popliteus muscle. This latter is the rationale for the posteromedial incision for drainage of a popliteal abscess. The fascia of the semimembranosus and the popliteal fascia form a continuous sheath overlying the posterior compartment of the joint. Incisions from the posteromedial surface of the tibia can be followed along the anterior surface of the popliteus muscle to the postero-external aspect of the knee. Furthermore, this incision can be carried to the posteromedial condyle of the femur by dividing the insertion of the semimembranosus to the posterior part of the tibia. This permits adequate drainage of the posterior aspect of the knee, without exposing the popliteal vessels; such exposure in the presence of pus and drains may often lead to serious secondary hemorrhage, and not infrequently to amputation.

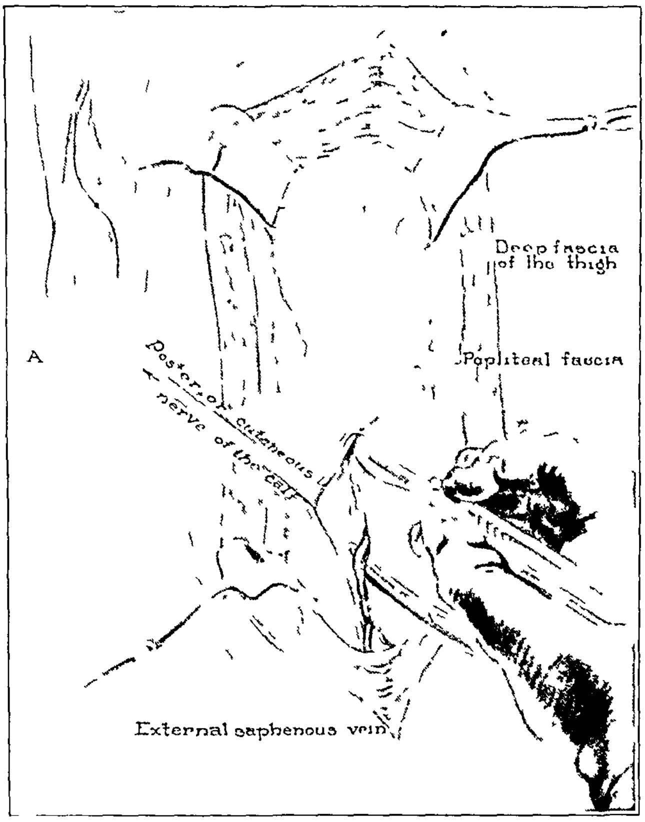


FIG. 26

The mid-line approach to the popliteal space with exposure of the posterior cutaneous nerve of the calf.

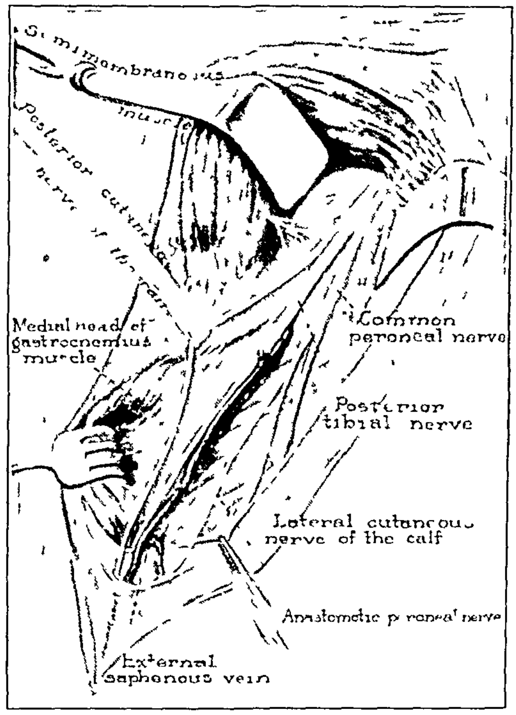


FIG. 27

The mid-line incision with exposure of the sciatic nerve and its divisions.

A. *Parapatellar Incisions*

1. *Indications:*
   a. Drainage of the anterior compartment of the knee joint.
2. *Position of the patient:* The patient is supine with the knee in slight flexion.
3. *Landmarks:*
   a. Patella;
   b. Joint line;
   c. Condyles of the femur;
   d. Head of the fibula.

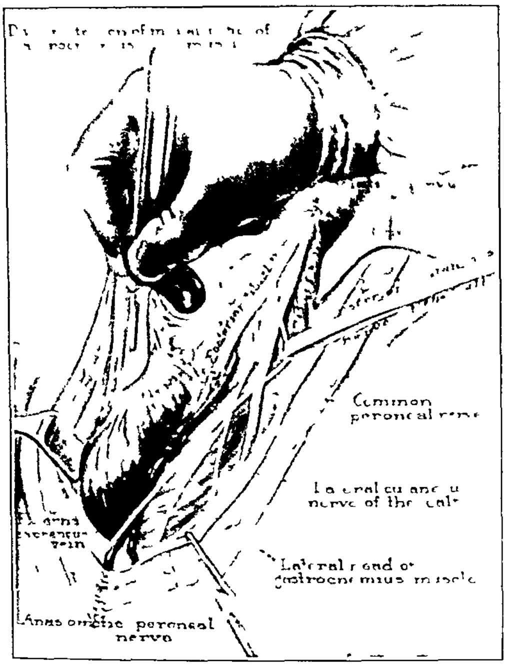


FIG. 28
The mid-line posterior approach to the popliteal space with exposure of the medial head of the gastrocnemius muscle.

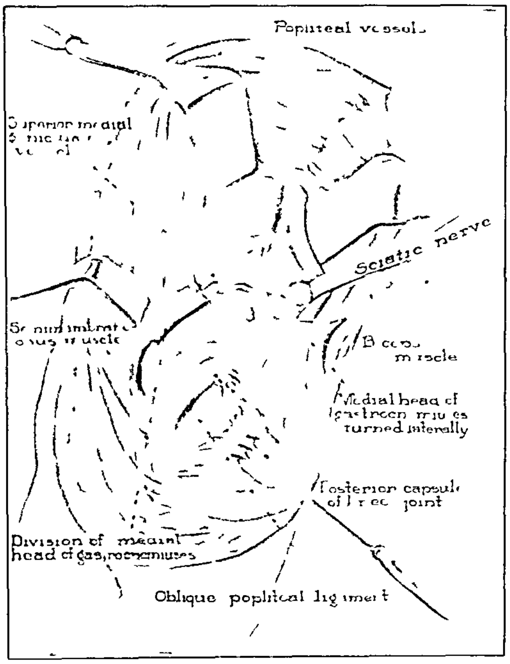


FIG. 29
The mid-line posterior incision with division of the tendinous origin of the medial head of the gastrocnemius and exposure of the capsule of the joint.

4. *Incision:* Two vertical parapatellar incisions are made on both sides of the knee They extend from the apex of the patellar pouch above to the margin of the tibia below. Alternative vertical incisions are of the multiple short variety, or two horizontal incisions may be made extending backward from the middle of the patella to the anterior margins of the collateral ligaments In these incisions, it is often necessary to sew synovial membrane to the skin to ensure adequate drainage, as no drains are placed within the joint.

B. *The U-Shaped Incision*

1. *Incision·* A U-shaped incision is also useful for compound fractures with severe sepsis. In the last War one of the writers (L C A) used it as a life-saving measure or as a preliminary to amputation The incision is made through the skin, patellar tendon, the deep fascia, and aponeurosis of the vasti. The U-shaped flap is turned upward, opening the joint widely The patellar tendon is stitched to the skin on the anterior aspect of the thigh. With the knee flexed, excellent drainage is secured.

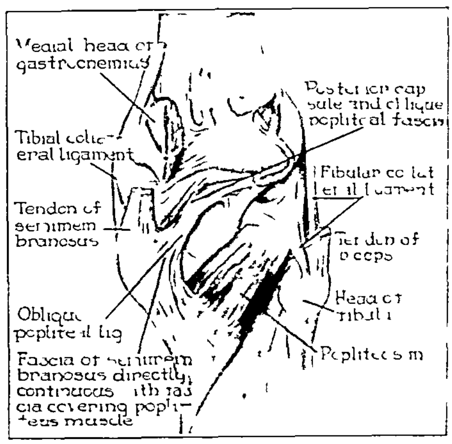


FIG 30
Dissection of the popliteal space (Redrawn from Spalteholz)

C. *The Posteromedial Tibial Incision*

1. *Indications:*

a. Drainage of popliteal abscess.

2. *Position of the patient:* The patient is supine, with the knee flexed to 30 degrees, and the hip in external rotation. The side of the foot rests on the opposite tibia. The prone position may also be used with the entire lower extremity on a sandbag well above the level of its fellow.

3. *Landmarks:*
   a. Posteromedial border of the tibia;
   b. Posteromedial border of the condyles of the femur;
   c. Internal hamstring group.

4. *Incision:* An incision, four inches in length, is made through skin and subcutaneous tissue over and well behind the posteromedial border of the upper one-fourth of the tibia to avoid exposure of the saphenous vein and nerve. These structures lie anteriorly in the subcutaneous fat, the vein usually in two divisions, one placed subcutaneously and the other lying in the subfascial portion. The deep fascia is incised in line of the skin incision, and the soft parts are drawn forward to expose the posteromedial border of the tibia.

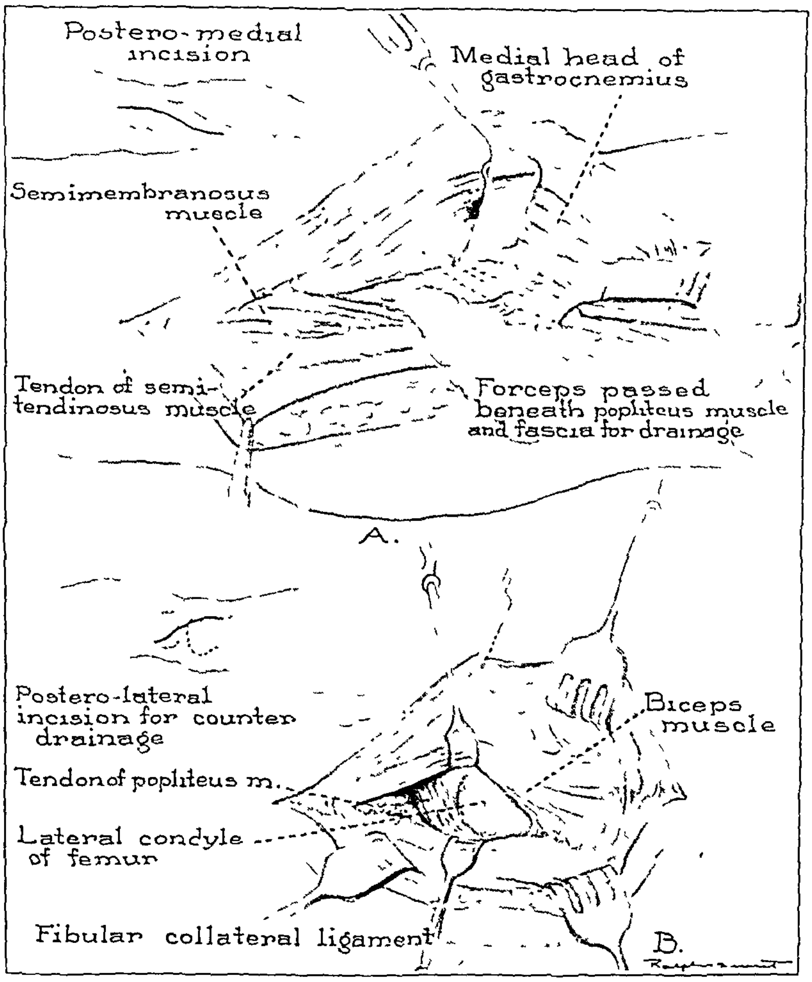


FIG. 31

A: The incision on the posteromedial aspect of the upper end of the tibia and the lower end of the femur for drainage of popliteal abscess.
B: The posterolateral incision for counter-drainage of popliteal abscess.

The posteromedial border of the tibia and the fascial covering of the medial head of the gastrocnemius are now exposed. This fascia is incised, and the gastrocnemius muscle is traced upward as far as its tendinous insertion of origin from the femur. The muscle is separated from its fascial covering to permit its retraction inward. The posterior surface of the upper end of the tibia is now displayed. Upon it lies the popliteus muscle and its insertion into the medial side of the tibia at the oblique line. From the oblique line, passing downward and medially, the fibrous origin of the soleus from the tibia is seen. The popliteus muscle is covered by fascia which is directly continuous with the fascia overlying the semimembranosus (Fig. 30). At the upper border of the popliteus, the inferomedial genicular vessels are disclosed; while lateral and posterior to the popliteus, the posterior tibial nerve and artery can be felt as they are crossed by the tendon of the plantaris. The insertion of the popliteus into the tibia is divided, and the clamp passed upward and outward along its anterior surface until it reaches the external condyle of the femur (Fig. 31, *A*). This pad of muscle and popliteal fascia forms a protection for the popliteal vessels, veins, and nerves which lie posteriorly.

During the last War, in cases of marked sepsis of the knee, it was our practice to carry the incision upward with division of the tendons of the sartorius, gracilis, and semitendinosus, and the capsule of the knee joint on its posterior medial aspect. In addition, counter-incisions were made over the posterolateral aspect of the joint to ensure better drainage. A more conservative procedure would be the posteromedial incision over the tibia, com-

bined with the operation described by Klein. This operation, with counter-incision over the postero-external aspect of the joint, gives complete drainage without undue hazard to vital structures.

D. *Arthrotomy of the Knee by a Posteromedial Femoral Incision* (*Klein*)

1. *Indications:*
   a. Drainage of the posteromedial aspect of the knee in sepsis.
2. *Position of the patient:* The patient is placed in the prone position, with the leg supported on a sandbag which raises it well above the level of the opposite leg.
3. *Landmarks:*
   a. Medial hamstring muscles;
   b. Medial condyle of the femur;
   c. Joint line;
   d. Upper medial margin of the tibia.
4. *Incision:* The incision is four inches in length, and is made over the posteromedial aspect of the knee, just lateral to the semitendinosus, its center being over the line of the knee joint. The subcutaneous fascia is incised, and the tendons which are exposed are the sartorius, the gracilis, and the semitendinosus, lying over the posterior and the posteromedial aspects of the internal condyle of the femur. Directly posterior to the sartorius is the saphenous branch of the arteria genus suprema. On the surface, but deep to the fascia lata, is the internal saphenous vein. The intervals between the gastrocnemius and the semimembranosus are identified, and the gastrocnemius is then followed up to its insertion into the medial condyle of the femur. In this latter interval between the gastrocnemius and the semimembranosus, the capsule is exposed and incised.

E. *Incisions for Counter-Drainage on the Posterolateral Aspect of the Knee.*

1. *Incision:* Curved or straight incisions for drainage on the posterolateral surface of the knee are made between the iliotibial tract and the biceps tendon. The capsule is incised behind the fibular collateral ligament, with exposure of the tendon of the popliteus muscle where it inserts into the lateral epicondyle of the femur. If used with the posteromedial approach, through-and-through drainage is obtained (Fig. 31, *B*).

SUMMARY

In this article the writers describe the anatomical details of the surgical approaches which they have found to be the most successful in operations upon the knee joint. This judgment is based upon their clinical experience and that of their colleagues (including a study of motion pictures taken while operations upon this joint were being performed), upon a comprehensive review of the available literature on the subject, and upon a survey of a number of dissections performed on cadavera and freshly amputated specimens.

The writers wish to express their appreciation to Dr. John B. deC. M. Saunders, Professor of Anatomy, who has been generous with his time and his exact knowledge of both human and comparative anatomy.

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ADJUSTABLE CASTS IN THE TREATMENT OF JOINT DEFORMITIES*†

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The value of supporting plaster casts for the prevention and correction of deformities ı joint disease, particularly in rheumatoid arthritis, is well recognized. Support of an ıvolved joint, which is kept flexed by muscle spasm, permits the spasm to subside, and llows the flexion deformity to diminish. The simple bivalved variety of cast has been sed successfully for many years on the Arthritis Service at the Massachusetts General Iospital. Bivalved casts have been used so that they could be removed several times a ay, in order that the joints might receive hot packs and exercises in bed, important feaures of the treatment. As soon as a flexion deformity had decreased by 10 degrees or so, new cast of the same type was made, thus permitting further relaxation of the joint.

For the past two and a half years these bivalved casts have been made adjustable by he application of hinges. Adjustable casts, particularly for knees and elbows, have been ound to possess several advantages. Much time, material, and labor are saved by avoidng the necessity of frequent renewal of an entire cast when the deformity is improving, or hen, as occasionally occurs during an exacerbation of the disease, it is temporarily inreasing. Compensation for variations in the amount of flexion deformity can be more

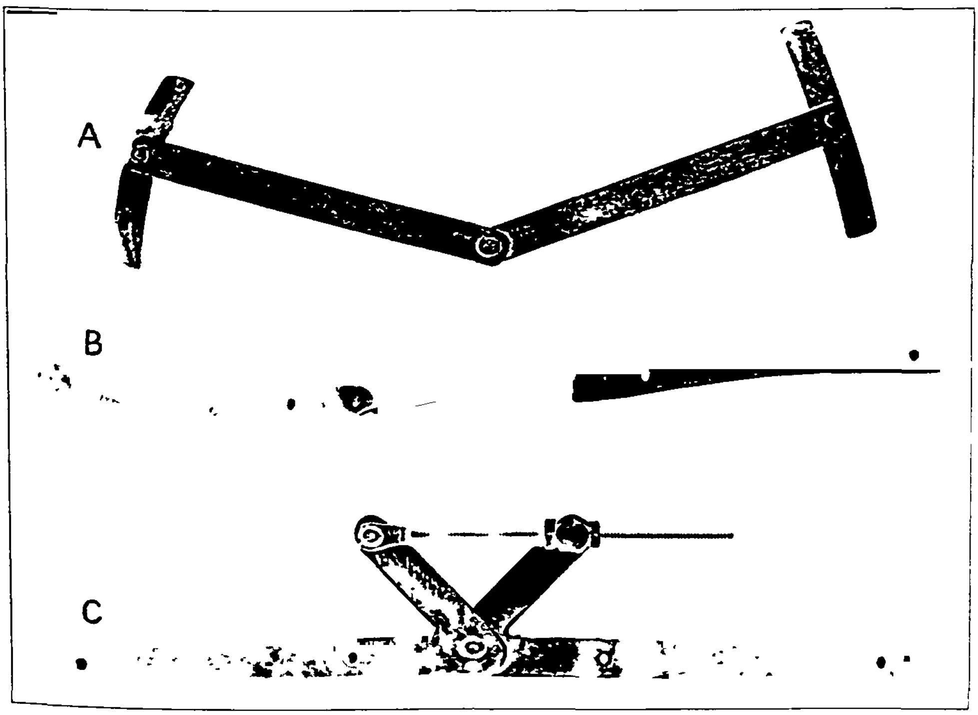

FIG. 1

Types of hinges used in pairs for knees (*A*, *B*, and *C*) and elbows (*A* and *B*).

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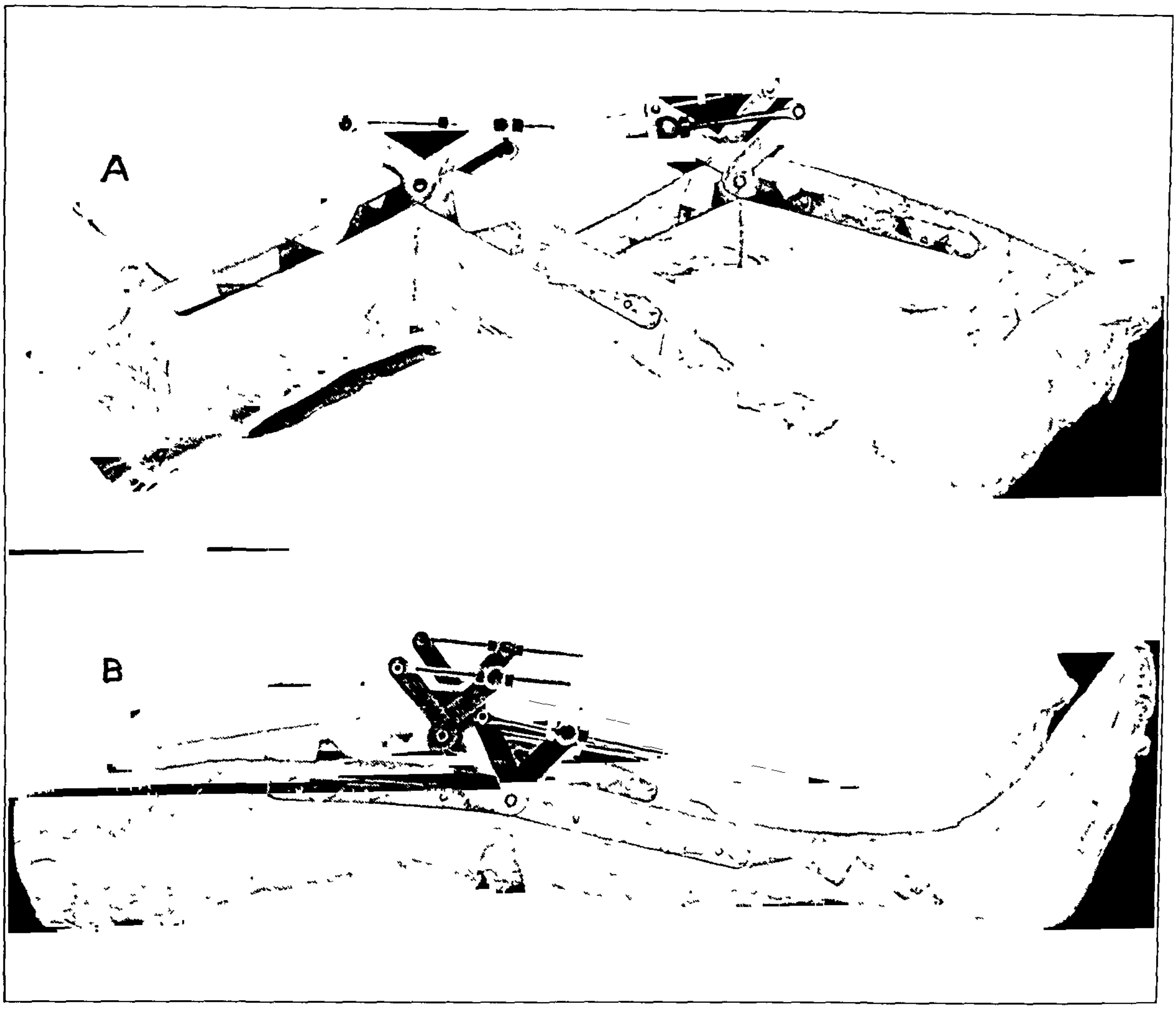

FIG. 2

Posterior shells of two leg casts with screw-type hinges (See Fig. 1, *C*).
A: Position of flexion deformity in which casts had been applied.
B: Corrected position obtained.

accurately achieved by a mechanical adjustment, which can be altered daily if necessary. A cast which accommodates itself to the deformity closely at all times is most effective in accomplishing relaxation of the muscles which are in spasm about an inflamed joint.

The photographs demonstrate the varieties of adjustable casts employed on knees. The two bivalved types shown in Figures 2 and 3 are used most frequently. The non-removable type illustrated in Figure 4 is occasionally employed on selected patients. The metal hinges * (Fig. 1) used on all casts have been easily made in the Orthopaedic Workshop of the Hospital. One pair of hinges is used repeatedly on successive patients.

The casts shown in Figure 2 are employed on joints with severe flexion deformities of an acute or subacute nature. The casts are applied cylindrically over two thicknesses of sheet-wadding from toe to groin, with the ankle and knee in as fully corrected position as is possible without strain. As soon as the plaster has set, the cast is bivalved, making the posterior shell about twice as deep as the anterior shell. The cast is removed and the sheet-wadding discarded. The plaster shells are placed in a warm cabinet for drying. A pair of metal hinges (Fig. 1, *C*) is riveted to the posterior shell, at the level of the femoral condyles. After the hinges have been attached, the plaster is sawed across to permit

* The hinge, shown in Figure 1, *C*, is a modification of Turner irons as regards construction, but it has the important functional difference that the undesirable element of constant pressure, generally exerted by Turner irons, is eliminated.

This is, as far as we know, the first time that hinges of the type shown in Figure 1, *A* and *B* have been used on adjustable casts.

motion as the hinge is adjusted. The anterior shell is only partly sawed through, from each side. The middle segment of plaster overlying the patella is fractured to act as a hinge. Adhesive plaster and leather, riveted in place, are used as reinforcement, permitting sufficient flexibility to accommodate this shell to the altered positions of the posterior, supporting shell. Finally, after irregularities on the inner surface of the plaster have been smoothed off, the cast is padded. Two thicknesses of sheet-wadding or a thin layer of soft felt are covered by one thickness of stockinette, fastened to the edges of the plaster by adhesive tape. The stockinette follows closely the contours of the cast. It is important that the stockinette should nowhere act as a sling. This is especially difficult to prevent at the heel, where the avoidance of pressure is most important. The stockinette should be laid loosely but evenly along the bottom of the depression for the heel. This produces a fold of stockinette on either side. These folds should be cut out, and the cut edges of stockinette overlapped by a strip of adhesive down each side of the heel.

The hinges (Fig. 1, *C*) are attached to the posterior shell of the cast by rivets. Adjustment of the hinges by the lock nuts on the screws is readily carried out with a pair of pliers. The nuts must be kept tight enough to prevent the patient from turning them himself. In making an adjustment, care is taken that the cast is not extended far enough to put strain on the affected joint, rather than to support it at rest, as is necessary to relieve muscle spasm. In other words, when a cast is adjusted, extension is increased only to the amount of taking up the slack between the present position of maximum extension obtainable without strain and the position at the last adjustment of the hinges.

This type of hinge (Fig. 1, *C*) is used on hospital patients who have severe flexion deformities. When a patient has only a mild flexion deformity, or is going to wear the cast at home, the type of "hinge" shown in Figure 1, *B* is employed. Plaster shells are made as already described. A metal strip, the central portion of which has been twisted through an angle of 90 degrees, is riveted to either side of the posterior shell at the knee (Fig. 3). By the use of "bending irons" (or two monkey wrenches) on the central portion of each strip, the flexion at the knee can readily be increased or decreased. It is essential that the metal strip be fairly stiff. The middle, flat portion need be only long enough to accept readily the bending irons. The leather hinge, used on the anterior shell of this type of cast, is the same as that described previously.

Bivalved casts with one of the above types of hinge are worn at night and for part of the morning and afternoon. It is essential that they be removed for regular periods every day. During such intervals hot packs are applied to the joints, and the patients are permitted to move their joints freely in bed, or are given supervised exercises without

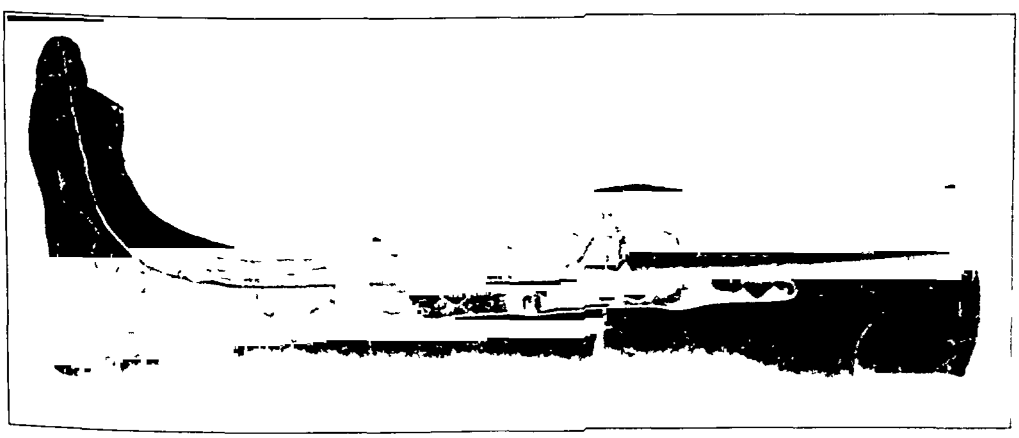

Fig. 3

Anterior and posterior shells of leg cast with bendable strip "hinges" (See Fig. 1, *B*). Position of final correction.

weight-bearing. When the patients are awake and in the supine position, and are cooperative, it is not necessary for the tops of the casts to be used. At night the tops are held in place by webbing straps.

These bivalved casts are employed on joints where it can be expected that relaxation of muscle spasm by simple support of the limb for periods during the day and night will bring about correction of a recently acquired flexion deformity. On carefully selected patients in whom the flexion deformity is of long duration and has not responded to a bivalved cast, an adjustable cast (Fig. 4), which embodies a more constant corrective factor, can be used, if synovial inflammation is absent or relatively quiescent. This cast is non-removable, and, while extension is being gained, there may be an associated loss of flexion. Such a cast is used, therefore, only when straightening a leg is of paramount importance,—as for instance when walking is the primary concern.

A well-padded plaster cylinder is applied from toe to groin, with the knee in maximum free extension; and it is not bivalved. After the plaster has hardened thoroughly, a pair of simple metal hinges (Fig. 1, *A*) is attached opposite the femoral condyles with plaster bandages (Fig. 4). The axis of rotation on each hinge should be situated slightly anterior to the axis of the femoral condyles about which the tibia rotates. This produces a tendency for the joint surfaces to be distracted, as the cast is extended. It is important, however, that the cast axis of rotation should not be too far anterior, for that would induce too great a shift of the cast on the leg, as it was flexed and extended.

The cast is sawed circularly at the level of the hinges. The sawing at the two sides should be carried out before the hinges are placed. After the hinges are firmly attached, sawing the front and back can be readily completed. The plaster over the patella should be removed, as well as that over the dorsum of the foot (Fig. 4, *C*). The latter permits exercise of the ankle. A segment of plaster may also be removed from behind the knee to allow additional flexion during the exercise periods. Since such a cast does shift somewhat on the leg as extension is gained, it is very important to watch closely for excess pressure on the skin at any point, and to question the patient on this score. Development of undue pressure can be avoided by anticipation. The cast in the photograph has been cut out over the lateral malleolus to prevent such pressure.

During most of the twenty-four hours, maximum extension of the knee is maintained by placing a block of wood in the gap in the cast behind the knee (Fig. 4, *B*, white arrow). A notch in each end of the block keeps the latter from falling out. Hardening the cut edges of the cast with several coats of collodion makes the block easier to insert and remove without fraying the plaster. Again, it is essential that no force be used in inserting the block. Forcible extension produces pain and protective muscle spasm, thus retarding the correction process. A longer block of wood to fill the widening gap is adopted only when sufficient slack for further free extension has developed, usually after five to seven days.

It is extremely important that motion at the affected joint be performed daily. The block is removed for brief periods several times a day for active exercise. The photograph (Fig. 4, *A*) shows the ankle in a sling, which is rigged to a handle by a pulley on a Balkan frame, to aid the patient in exercising the joint by himself. It is much safer to use a block of wood than an adjustable mechanical device to maintain extension in these casts, because in this way it becomes impossible for anybody inadvertently to apply more extension than the length of the block produces. Such a cast must not rest on the heel, as that would lead to strain at the knee joint. The cast should be supported by a pillow beneath the calf of the leg.

It must be emphasized that this type of non-removable cast is used only where it is thought to be more important to gain maximum extension of the leg than to preserve maximum motion at the joint. Even so, while extension is being accomplished, all possible motion is preserved by the frequent removal of the block for exercise of the joint.

For elbows, adjustable casts are used with similar precautions. All casts are applied

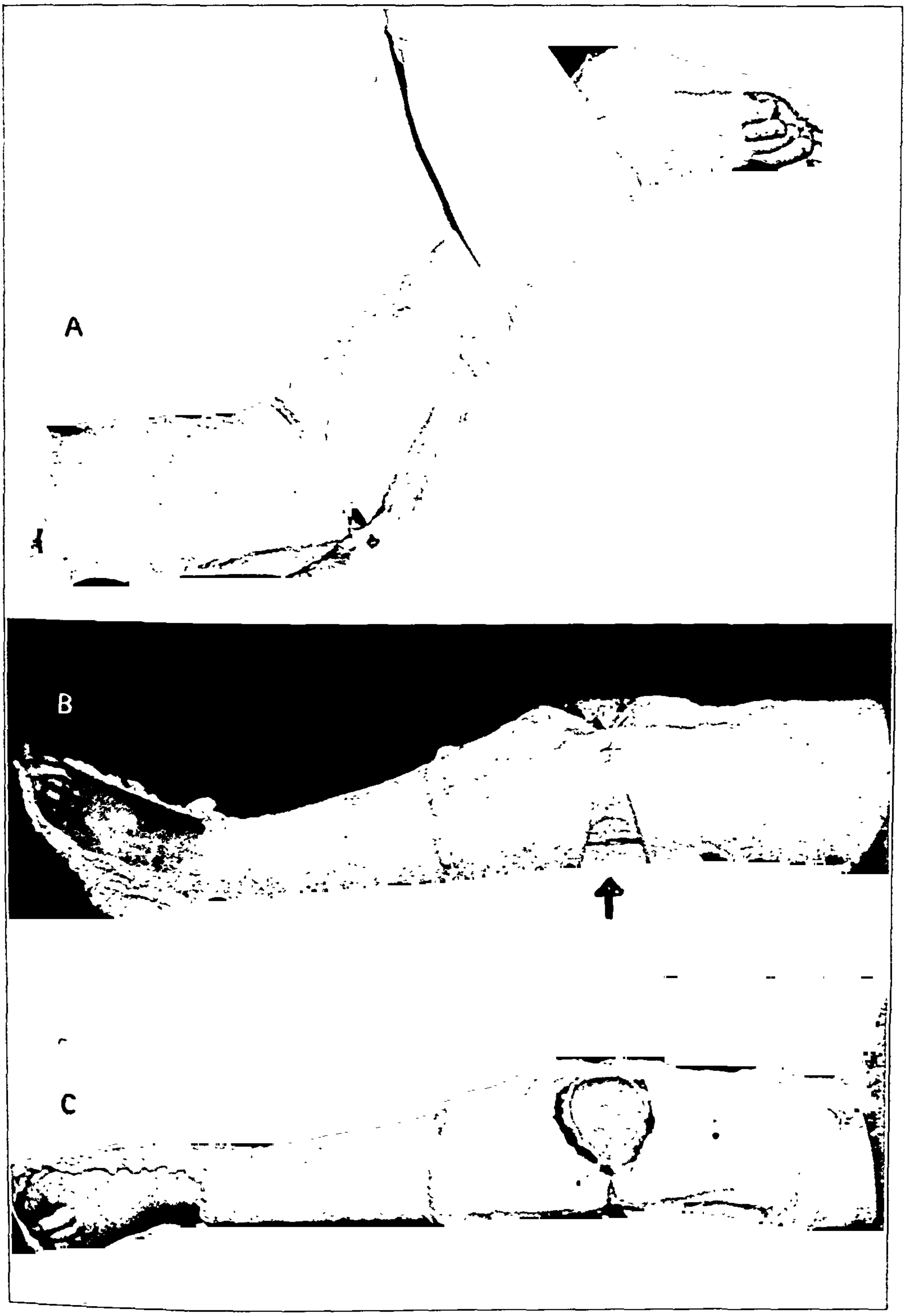

Fig. 4

Non-removable cast with simple hinges (See Fig. 1, *A*).
A: Position of original flexion deformity in which cast had been applied.
B: Extension which had been gained. Arrow points to removable wooden block behind knee.
C: Anterior view.

in maximum free extension. It is important to place the axis of rotation of hinges opposite the humeral condyles, and not opposite the olecranon. When bivalved casts are employed, the metal strip "hinges" which are adjustable by bending irons are used (Fig. 1, *B*). The more elaborate screw type of hinge (Fig. 1, *C*) would be too bulky for the elbow. The metal strips are riveted to the deeper posterior shell, and a segment of plaster is cut out over the olecranon to permit extension. The anterior shell is partially cut, fractured, and reinforced with leather, as on knee casts. Non-removable casts with simple hinges (Fig. 1, *A*) and a wooden block are employed for the same indications as in the knee. The details of the application and the cutting of the casts are also essentially similar.

Bivalved and solid casts, with adjustable screw hinges or with bendable metal strips, have been employed in the correction of equinus and varus deformities at the ankle. Volar wrist splints, which are held in place by webbing straps, have been fitted with bendable metal strips to accommodate them to gains in extension. By far the most frequent and valuable use of adjustable casts, however, has been for knees and elbows.

SUMMARY

Types of adjustable plaster casts which have been used advantageously for the treatment of flexion deformities of knees and elbows in patients with rheumatoid arthritis and other joint diseases have been described. Such casts remain effective for many weeks, and represent a great saving of time and labor as compared with the practice of making an entirely new cast every week or two, as the deformity of a joint improves. Furthermore, in comparison with other varieties of casts and traction, it has become apparent that these hinged casts, kept well adjusted to the joints and without strain at all times, provide the most effective correction of deformities. The importance of daily exercise of the joints without weight-bearing cannot be too strongly stressed. Although adjustable casts exhibit their chief value for knees and elbows, they are useful occasionally at other sites

RESEARCH WORK ON A MORE PRECISE METHOD OF DETERMINING MUSCLE STRENGTH IN POLIOMYELITIS PATIENTS

A New Muscle Tester *†

BY ADOLPH A. SCHMIER, M.D., NEW YORK, N.Y.

The purpose of this study has been to devise a more accurate method of determining the strength of muscle groups in poliomyelitic patients. The work was instituted at the Hospital for Joint Diseases and has been carried out on the Services of Dr. Leo Mayer, Dr. Harry Sonnenschein, Dr. Henry Milch, and Dr. Jerome Weiss.

The assumption that a single muscle can contract without stimulating agonistic as well as antagonistic muscles is not generally true. We are unable to evaluate the actual strength of individual muscles unless all neighboring muscles have lost their function, either by loss of innervation or by their section. Even the strength of a group of agonistic muscles cannot be definitely determined, unless we allow for the action of antagonistic muscle groups. Actually, we test the resultant action of a group of muscles to move a segment of the body about its axis of motion, or joint; and the strength with which it can do so. The strength with which a segment of the body moves also depends upon the synergistic response of distant muscles, which by their action do not even move the segment being tested. These latter muscles fix or stabilize the neighboring movable part of the body, in order to allow the muscles being tested to have a firm origin from which to pull. For instance, during knee extension against resistance, with the patient either in the sitting or side-lying position, the hip extensors tend to fix the thigh in complete extension. Without such thigh stabilization, the knee cannot be extended with maximum strength. If two patients with exactly equal knee-extension power but unequal hip-extension power were examined, it would be found that the recorded knee-extensor strength would be stronger in the case with stronger hip extensors. In other words, a patient cannot use a muscle group to the greatest advantage unless distant muscle groups, which have no primary action in moving the tested segment around its joint, function synergistically so as to enhance the power of the muscle group being tested by stabilizing the adjacent body segment. This principle is taken advantage of when testing patients with the scale method, by stabilizing the adjacent segments mechanically.

For practical purposes, we can enumerate the various muscles which move a given segment of the body in a certain direction. We can then assume that the strength with which the segment moves in this direction is the actual strength of the muscles enumerated. In order to evaluate the proportional strength of each of these muscles separately, two methods are open to us. The first is the method of palpation. The examiner palpates the muscle in order to estimate its contractility and approximate strength. The result varies with the subjective knowledge and ability of the examiner and is, therefore, unreliable. The second method of determining the proportional strength of a single agonistic muscle is by employing the isolation test. It is carried out in such a way that the tested segment of the body is moved primarily by a single muscle. The other agonistic muscles are placed at a mechanical disadvantage by being completely relaxed; thus their effective action is minimized. For instance, the combined action of the gastrocnemius and soleus plantar-flex the foot. By completely flexing the knee, the gastrocnemius is relatively

* Presented to The New York Chapter of The American Physiotherapy Association, January 15, 1941, and to The New York Physical Therapy Society, February 5, 1941. A talking motion picture in color, illustrating the apparatus and technique of examining patients was exhibited at the ninety-second annual session of The American Medical Association in Cleveland, Ohio, in June 1941, and to The American Physiotherapy Association at Stanford University, Palo Alto, California, in July 1941.

† This research was aided by a grant from The National Foundation for Infantile Paralysis, Inc.

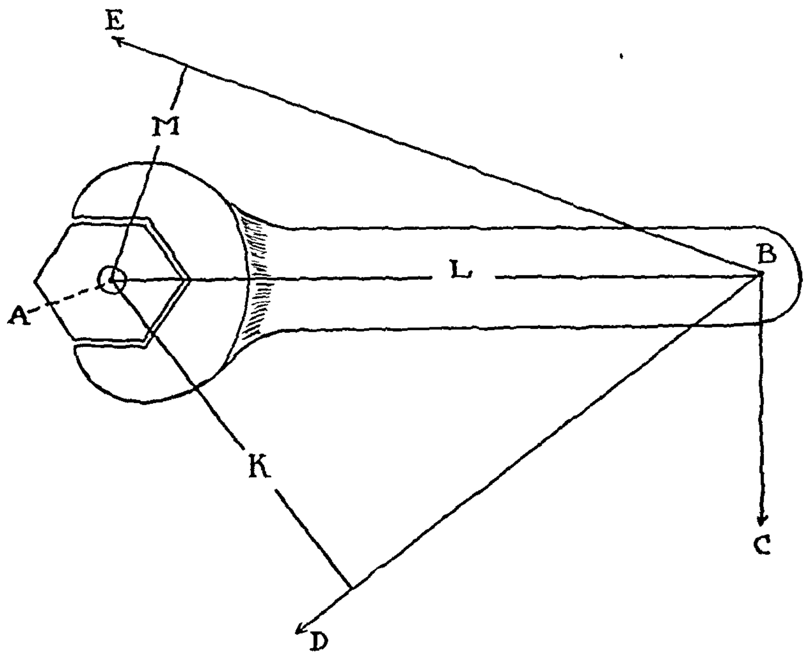

FIG. 1

Moment of force. An equal force acting through the spanner on the bolt *A* in the directions *BA*, *BE*, *BD*, *BC* will produce the greatest moment of force when acting along the direction *BC*. The moment of force depends upon:
1. The magnitude of the force acting.
2. The distance of the force from the axis of the body upon which it acts, measured along a line at right angles to the line of action of the force.

lengthened and relaxed, thereby diminishing its tension and its contracting efficiency. It is now unable to contract sufficiently to plantar-flex the foot with any appreciable power. The soleus, therefore, becomes primarily responsible for plantar-flexion of the foot.

It has long been known that the determination of muscle strength by the manual method is only approximate and attempts have been made, first by Lovett and Martin, to increase the accuracy of these tests. Some years ago, the writer began to employ a rectangular spring scale with ink pointer attachment in order to record the results in pounds and ounces. The original method has been reported in a previous publication.[4]

In order to record the maximum strength of a muscle group, the following principles must be adhered to. The scale must be strong enough to prevent the tested segment from completing its arc of motion. Each of the rectangular spring scales was so constructed that its indicator was required to go through an excursion of five inches for maximum recording. Since many body segments do not move normally through a 5-inch range, it was impossible to determine their maximum strength with these scales. It was, therefore, necessary to replace the rectangular scales with a single circular scale of sufficient strength to test the strongest muscle group in the body. Circular scales require a minimal arc of motion of their indicator, in order to record maximum strength. This applies equally to the circular-spring and gravity-lever type of scale. It was ascertained that either would be satisfactory, provided it is circular. A 180-pound scale of the gravity-lever type was obtained, permitting readings as low as four ounces. This scale requires a minimal arc of motion to record maximum strength. A maximum lever pointer was attached to the scale, thereby allowing the examiner to perform the test without the necessity of watching the scale. It was attached to the glass cover of the circular scale by means of a ball-bearing rotating joint. Its movement coincides with the movement of the regular indicator, and when the tested muscle relaxes, the maximum lever pointer retains the position of maximum muscle pull. It therefore allows the maximum muscle strength to be read after the test is completed. This scale is similar to that used by Mayer and Greenberg.[3] It differs in that it has a special housing, a special base, and a maximum lever pointer; it can be attached to the table in any desired position.

The table employed has been designed in order to test all important muscle groups of the trunk as well as the extremities with the least possible source of error and the least discomfort to the patient. It has a flat top surface with narrow trunk end and wide extremity end. Triangular sections of the top can be removed, allowing the trunk portion to swivel from side to side by means of a ball-bearing joint, when an appropriate lock is released. By stabilizing the pelvis, the strength of the muscle groups that move the trunk

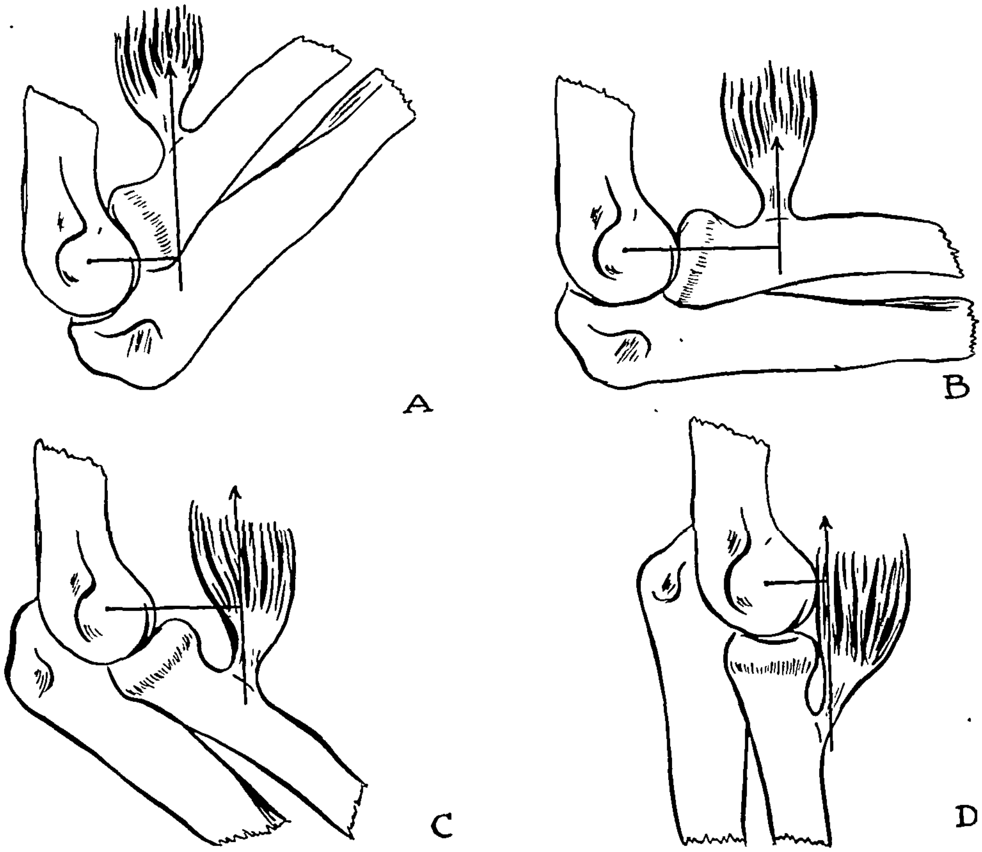

Fig. 2

Optimum angle for obtaining maximum moment of flexion force at elbow. From mathematical standpoint, the moment of flexion should be greatest with the tested movable segment at right angles to the neighboring fixed segment. In the human body, however, we must consider the position which gives the maximum muscle tension or muscle tone. In the elbow it is 180 degrees for the flexors. A combination of both factors determines the proper angle to measure muscle strength. The optimum angle for elbow flexion is 115 degrees.

can be determined. By locking the movable portion of the table, and replacing the triangular sections, an intact, flat top, table surface is obtained for testing the extremities. Two metal rails encircle the table. The upper rail permits the various appliances to be attached to it in any desired position for stabilizing the patient on the table. The scale is mounted on a triangular base with ball-bearing rollers and moves along the lower encircling rail. It can be fixed to the rail in any desired position. The tested body segment is attached to the scale by means of a web strap, in order to record the strength of its tested muscles. The scale and its housing are mounted on the base by means of a ball-bearing swivel joint, permitting the scale to swivel on its long axis. By this means, the scale follows the movement of the tested body segment, allowing a right-angle pull on the scale at all times. The various appliances stabilize adjacent body segments, permitting movement of only that segment whose activating muscles are being examined.

The conditions under which the tests are made should be uniform. This is important when interval examinations are repeated on the same patient in order to determine progress. The examined segment should be uniformly warm. A cold extremity cannot function as well as a warm one. The technique for testing each group of muscles has been carefully devised and standardized. It is important to note that wherever possible the tests are performed with gravity eliminated. This is possible in all instances except where rotatory movements are being performed. Particular attention is paid to proper stabilization in order to avoid substitution action. Before a given test is carried out, the tested

segment should be passively moved through its complete arc of motion. This will reveal any existing contractures, which by their presence hinder free action of the muscles being tested. In the presence of fixed contractures, free joint movement cannot be obtained, and the readings must, therefore, be accepted with reservation.

When examining the strength of muscle groups, one must have some knowledge of the mechanical events occurring during muscle action. (The amount of work performed by a contracting muscle is the product of the force used by the distance or extent of movement. $W = F \times D$. One unit of work is the amount involved in exerting one unit of force through one unit of space. Work is ordinarily measured in gram-centimeters or foot-pounds.) In this study we are primarily interested in measuring the force expended by the tested muscle group in attempting to move the segment against resistance. A force is characterized by its magnitude, its point of application, its direction, and its sense,—that is, whether the force is push or pull at the point of application. In the human body, a muscle always exerts a pulling force at its point of application, or insertion. Forces may produce or tend to produce motion of translation,—that is, motion in a straight line. A force may be applied to a body to produce or tend to produce motion of rotation. In the human body, muscle action tends to produce motion of rotation of a segment about its joint or axis. The turning effect of a force which tends to produce rotation is called the moment of force. Its measure depends upon:

1. The magnitude of the activating force.
2. The distance of the force from the axis of the body upon which it acts, measured along a line at right angles to the line of action of the force.

These two factors together determine the turning effect, and their product is called the moment of force. From a mathematical standpoint, the moment of force, or muscle strength, will be greatest when the tested movable segment is at right angles to its neighboring fixed segment. In measuring muscle strength, however, one must consider not only the ideal mechanical principle, but also the position in which the tested muscle possesses its maximum tension or muscle tone. In the human body, therefore, these two factors determine the moment of force. For example, one would expect the moment of force of the elbow flexors to be greatest with the elbow at 90 degrees, and with a web strap from the scale attached to the forearm at the level of insertion of the biceps and brachialis anticus. At 90 degrees, however, the tension of the elbow flexors is less than when the elbow is at 180 degrees. An optimum relationship between the mechanical principle and muscle tone had to be determined for each joint movement, in order to obtain the greatest moment of force. Testing his own right elbow flexors, the author obtained the following results when the angle of the elbow was in the following positions:

Elbow at angle of 175 degrees, force equals 21 pounds.
Elbow at angle of 155 degrees, force equals 36 pounds.
Elbow at angle of 135 degrees, force equals 42 pounds.
Elbow at angle of 115 degrees, force equals 44 pounds.
Elbow at angle of 90 degrees, force equals 36 pounds.

The technique devised for testing all muscle groups in the body has been based upon the principles already outlined.

A total of 367 patients have been examined with this apparatus. Of these, 237 were "normal", and 130 were poliomyelitic patients. Twenty of these cases, including five "normals" and fifteen poliomyelitic patients, were examined with the spring scale, before the original table was made. Of the total number examined, 234 cases, including 173 "normals" and sixty-one poliomyelitic patients, were examined with the spring scale and muscle-testing table. The remaining 113 cases have been examined with the latest apparatus, consisting of a gravity-lever type of scale and swivel table. Only one person

is necessary to adjust the patient and the apparatus. After the patient is in position, the examiner no longer plays an active part in the test. Any source of error relating to the examiner is, therefore, eliminated. The same test can be performed by more than one examiner with the same result, providing identical technique is employed.

This method of testing muscle strength in poliomyelitic patients is not being advocated to supplant completely the manual method of testing muscles. Patients whose

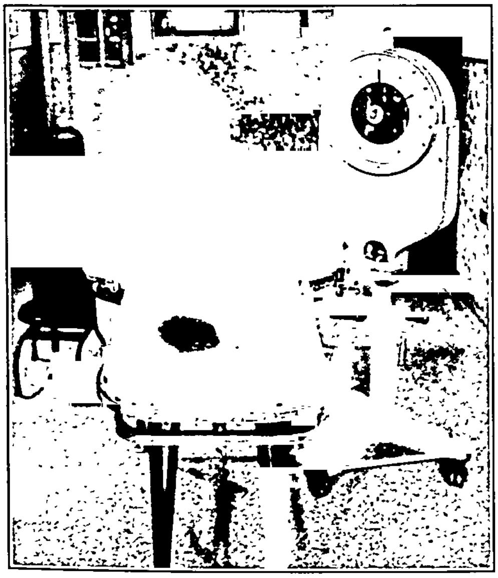

Fig. 3

New table and scale employed. Triangular sections of the table top can be removed, permitting narrow trunk end of table to swivel on a ball-bearing joint to test trunk-muscle strength.

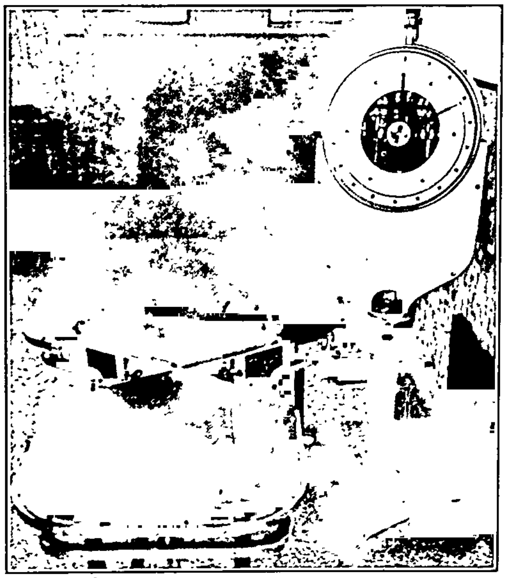

Fig. 4

Table with triangular sections removed, revealing the circular ball-bearing joint which permits the trunk end to swivel when lock on head end is released.

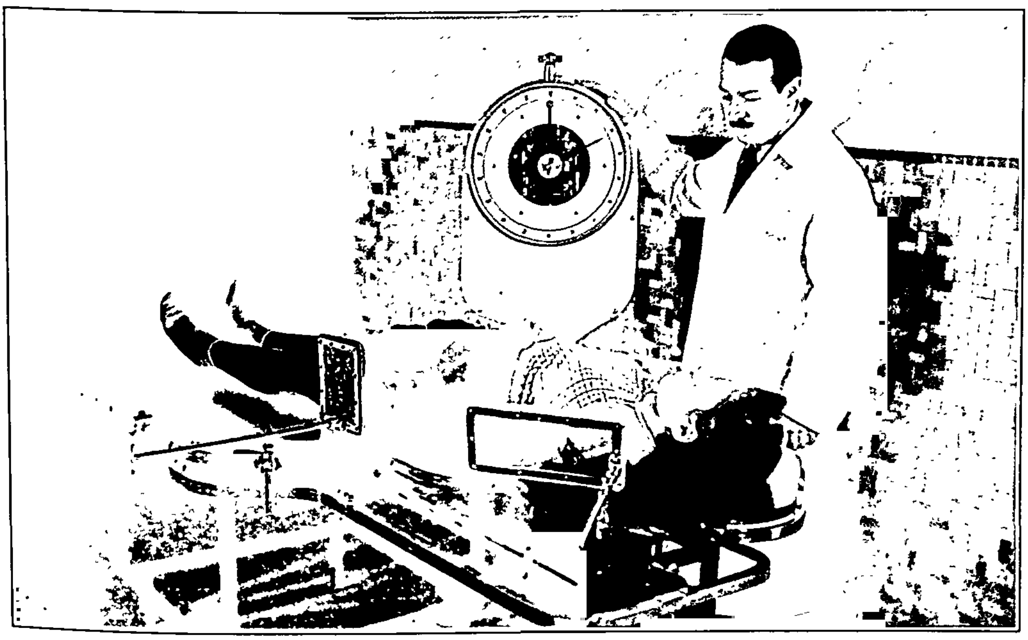

Fig. 5

Testing left lateral flexion of trunk (lateral abdominals). Note pelvis stabilized to fixed broad end of table; trunk is fixed to narrow movable portion of table.

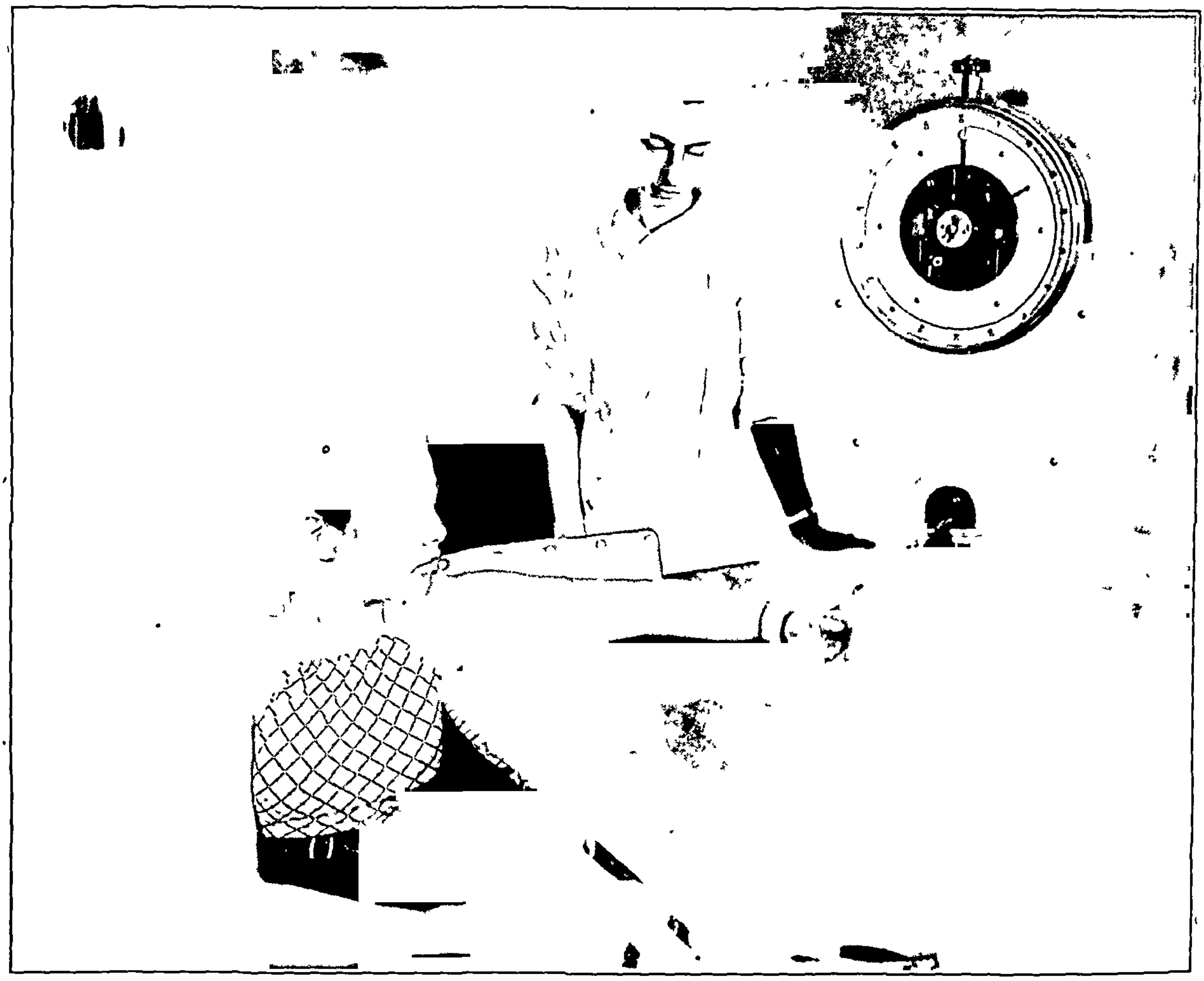

FIG. 6

Testing elbow flexors; elbow at 115 degrees Note stabilizer which fixes shoulder and upper arm. Gravity is eliminated. Table is powdered.

muscles have been so weakened that they rate only a *1* cannot be tested by the scale method. It is obvious that some active movement of the tested segment is essential in order to be recorded upon the scale. A tested muscle group must, therefore, have a manual strength of at least *2* in order to be recorded. In the latter cases, however, it is felt that the determination of muscle strength can be more accurately obtained by the scale method than by the manual method. An attempt has been made to correlate the findings in poliomyelitic patients with the average findings in normal individuals. The series of normal individuals examined were grouped according to age, height, weight, and sex, and the average strength of the various muscle groups was determined. The number of cases in each age group varied from three to seventeen, with a total of 237 normal cases examined. It is evident that the number in each group is too small to permit definite conclusions. However, a number of observations were made, and these can be checked by additional examinations. The strength of corresponding muscle groups varied considerably in patients in the same age class. Generally, the older the patient, the stronger were the corresponding muscle groups. This is not absolute, however, since many younger patients were found to be stronger than the older patients. The sex of the patient in the same age group gave no definite indication of the muscle strength. Quite often the female group was stronger than the male group. Similarly, the height of the patient bore no relation to muscle strength. It was not uncommon to find the shorter individual to be the stronger. The weight of the individual did not relate to muscle strength. It is evident, therefore, that the average strength of muscle groups may be quite different from the actual strength in normal individuals in the same classifications. An attempt was then

Fig 7

Testing supination of forearm. Note special brace which immobilizes wrist and articulates with rotating joint by means of metal rod. Elbow is at right angles, forearm begins in pronation of 90 degrees. Similar technique is employed with new table and scale.

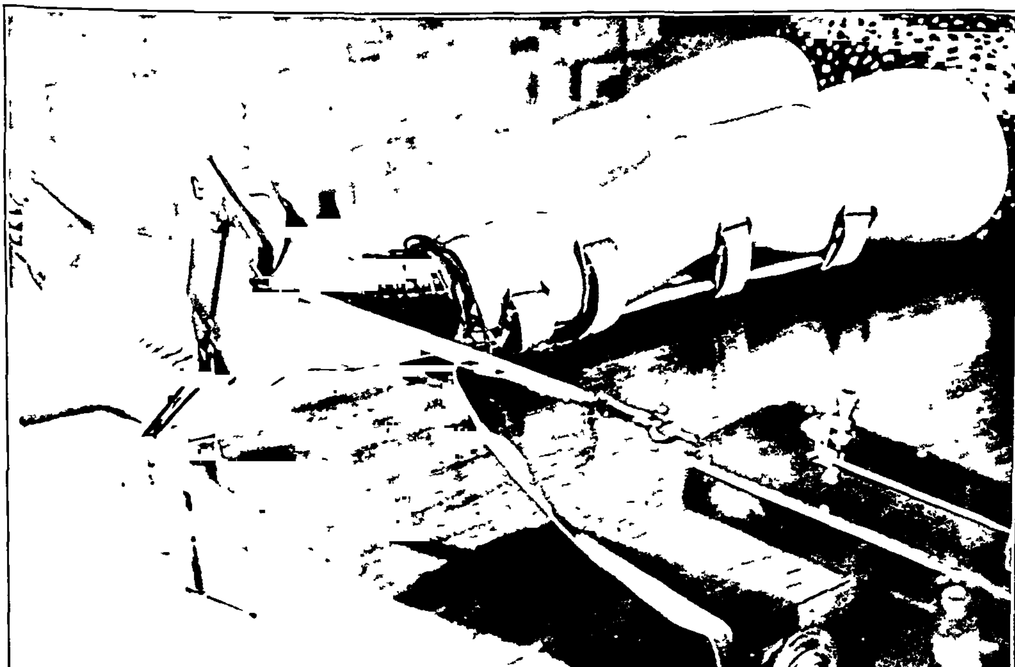

Fig. 8

Testing internal rotation of left hip. Tested leg is immobilized in special brace which maintains foot at 90 degrees and knee at 180 degrees. Foot piece, as well as leg trough, is extensible to fit extremities of various sizes. In addition, adults' and children's sizes are employed. Knob on heel of foot piece articulates with rotating joint, which on new table is attached to rail. Tested leg begins in external rotation of 45 degrees.

made to determine whether muscle strength was related to the length of the extremity (
to its segments; to segment area; or to segment volume. The length of the lower extrem

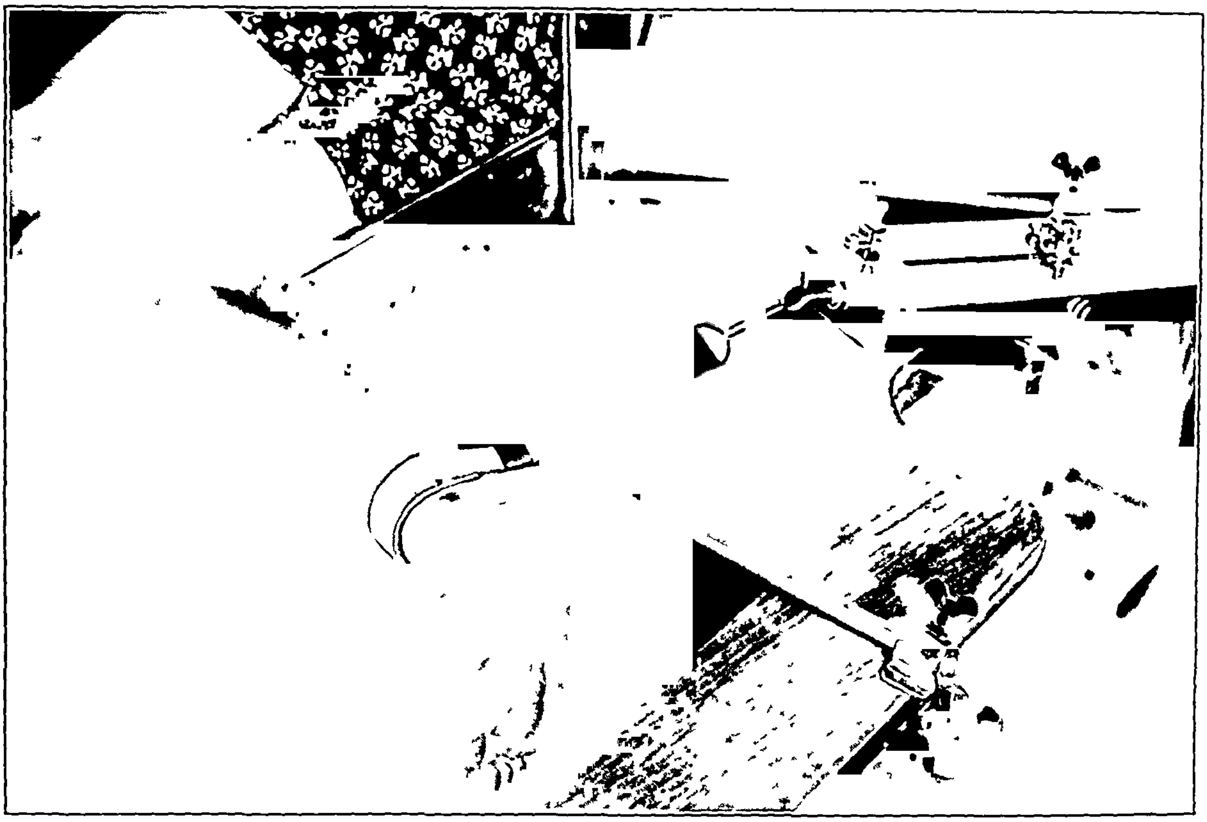

FIG 9

Testing extension of knee (quadriceps). Pelvis and thigh are stabilized at 180 degrees. Measurement of power begins with knee at 90 degrees.

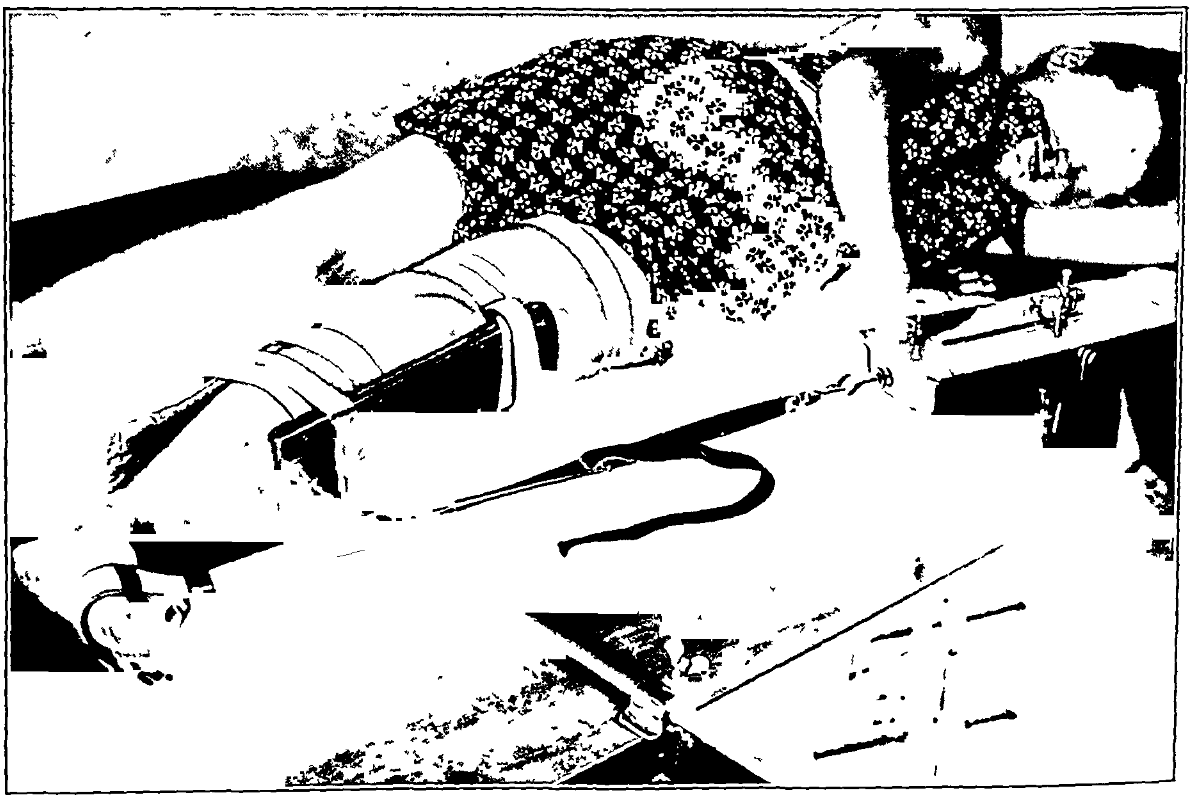

FIG. 10

Testing plantar flexion of foot. Knee is immobilized in extension. Recording of foot power begins with foot in maximum dorsiflexion.

ties of all patients was measured, as well as the length of the thighs and legs. It was found that the strength of the thigh muscles and leg muscles was not related to the length of the corresponding segments of the extremity. The length of each segment was then multiplied by the average circumference, but the results obtained bore no relationship to muscle strength. The volume of each segment of the lower extremity was then ascertained by a method similar to that used for determining the volume of a frustum. The following well known formulae were employed:

Volume = area × height. Area = π (3.1416) × R². Diameter = circumference ÷ π. The average area was determined by taking the measurements at each end of the segment and then dividing by two. The above calculations gave the volume of each segment. Disregarding bone, fascia, and fat, it was assumed that the results obtained were the volumes of the muscle mass. No definite relationship was noted between the volume and the muscle strength in each segment.

The strongest muscle group in the lower extremities was generally found to be the knee extensors. They were found to be definitely stronger than the antagonistic flexors in most cases. The plantar flexors of the foot were also found to be generally stronger than the dorsiflexors of the foot. The difference, however, was not great. The other antagonistic muscle groups of the lower extremities were found to balance each other more or less. The hip extensors were often found to be a shade stronger than the hip flexors; the hip abductors slightly stronger than the hip adductors; and the external rotators slightly stronger than the internal rotators.

The progress of infantile paralysis patients can be accurately charted by repeated examinations at stated intervals. For instance: Examination of a recent poliomyelitic patient disclosed the strength of the knee extensors to be seventeen pounds in one leg, and fifteen pounds in the other. (The average strength of this muscle group in normal children of the same age is about seventy-eight pounds.) After four months of treatment, a check-up examination revealed a gain in the involved muscle groups from seventeen to forty pounds in one leg, and from fifteen to thirty pounds in the other leg. A girl, eleven years old, with infantile paralysis involving the hamstring group was able to flex the knee with a strength of only ten pounds. (Thirteen normal eleven-year-old girls were able to bend their legs at the knee with an average pull of thirty-eight pounds.) The therapeutic value of electrical therapy, massage, and exercises was observed when, after less than four months of treatment, the stricken child had increased her knee-flexion power from ten to twenty-seven pounds. By detecting small differences of muscle strength at interval re-examinations, we will be able to control the form of therapy being given to the patient. The importance of determining the loss of even small amounts of strength in paralyzed muscles cannot be overemphasized. Excessive electrical stimulation, excessive massage, overexercise of paralyzed muscles, and improper splinting and bracing tend to weaken rather than strengthen these muscles.

Since minor changes in muscle strength are not readily detectable by the manual method of testing muscles, a muscle may gradually lose considerable power before the loss is recognized and the causative factor eliminated. When interval examinations with the scale method show a muscle to be weaker, the cause can be immediately investigated and corrected. By the scale method it will be possible to evaluate the comparative benefit derived from the various accepted forms of therapy presently in use. Small degrees of muscle imbalance, which if allowed to exist would produce deformities and contractures, may also be detected and corrected. In late cases of poliomyelitis, the value of accurate muscle testing may be important in determining indications for tendon transplantation.

The use of the scale method of testing muscle strength is not limited to infantile paralysis patients. The method can be employed in any condition of muscle weakness, if the full cooperation of the patient can be obtained, and he is willing to pull. It can be employed in cases of pseudohypertrophic muscular dystrophy, peripheral neuritis due to

injury or disease, congenital myatonia, and cases of quadriceps weakness following such operations as knee-joint arthrotomies. Although a fairly large number of patients have been examined, it is felt that further clinical work along this line should be carried on. It would be advantageous to have the work performed more generally, so that as many cases as possible in the convalescent stage of poliomyelitis could be examined. By this means, a universal method of examining patients might be established. The apparatus described is not only useful for examining muscle strength, but can also be employed for isolated muscle-group exercises. Therefore, it is of value in treating as well as in testing poliomyelitic patients.

The author wishes to express his appreciation to Miss Tova Schwartz and Miss Emmele Nansen for their aid in the technical examinations of the patients.

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REGENERATION OF THE PATELLA

A Case Report

BY W. P. CORRIERO, M.D., AND CHARLES AQUAVELLA, M.D., BROOKLYN, NEW YORK

From Kings County Hospital, Brooklyn

D.M., a colored female, sixty-three years old, was admitted on February 9, 1942, stating that on that day she had fallen on her right knee. Roentgenogram (Fig. 1) showed longitudinal and transverse fracture of the patella. Aspiration of the knee yielded 500 cubic centimeters of sanguineous fluid. The leg was put in Buck's extension, and swelling did not reappear. On February 26, after the abrasions on the skin had completely healed, the bone fragments of the patella were removed through a curved transverse incision. The joint was closed with No. 0 chromic sutures, and the tendons of the rectus femoris and the ligamentum patellae were sutured with No. 2 chromic mattress sutures. A posterior plaster mold was applied. Roentgenogram taken March 4, 1942 (Fig. 2) showed that the removal of the patella had been complete. The wound healed well. The patient was discharged on March 21, able to walk and to partially flex the knee.

FIG. 1

FIG. 2

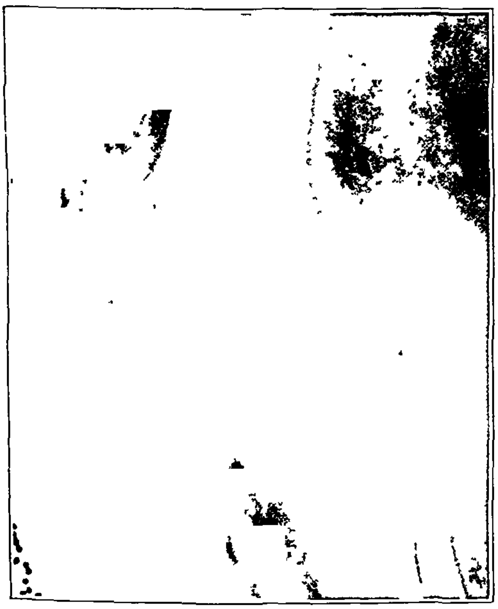

FIG. 3

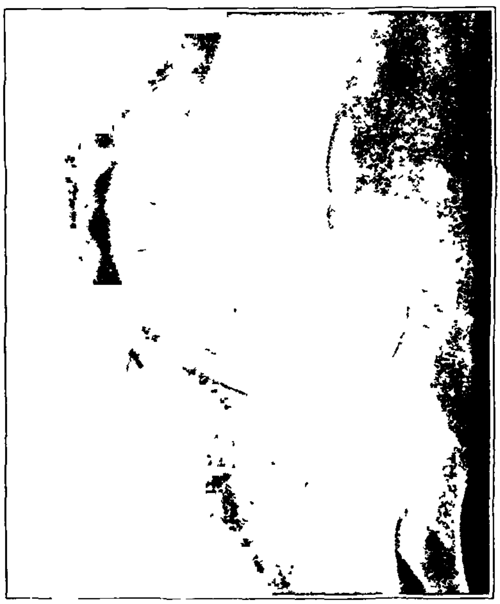

FIG. 4

Pathological report stated that all bone fragments of the excised patella could be fitted together, measuring 5 by 5 by 2.5 cubic centimeters, and evidence of neoplasm was not found.

On April 18, 1943, roentgenogram (Fig. 3) showed considerable calcareous deposit, presumably bone, at the site of the excised patella. On November 15, 1943, a firm bony patella could be palpated. The joint was stable in medial and lateral directions, and motion was from 80 degrees in flexion to 165 degrees in extension. The patient could walk about the room with only a slight limp, and could climb stairs with proper alternating stepping on the treads. She complained of pain in the knee, due probably to inability to fully extend the knee.

Roentgenogram (Fig. 4) revealed extensive regeneration of the patella and bony deposits in the patellar ligament.

TREATMENT OF FRACTURES OF THE OLECRANON BY FIXATION WITH STAINLESS-STEEL SCREWS

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From the Section on Orthopaedic and Traumatic Surgery, the Guthrie Clinic and Robert Packer Hospital, Sayre

It is impossible to reduce satisfactorily all fractures of the upper ulna without open reduction. Indeed, the only type of fracture which can be reduced under local anaesthesia and by external manipulation with towel clips, pins, and other devices is a simple transverse fracture of the olecranon where comminution is not present. Where there is comminution, especially in the articular portion of the bone, open operation is indicated,—first, to remove small articular fragments which might later interfere with joint function, and, second, to align properly the comminuted fragments.

Twelve cases of transverse fracture of the olecranon have been reduced without incision. Longitudinal fixation has been effected with long, slender, stainless-steel screws

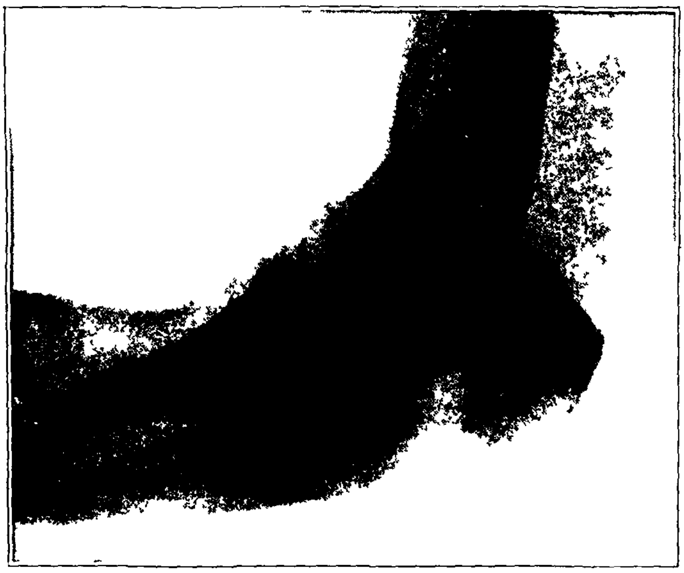

FIG. 1
Transverse fracture of the olecranon prior to fixation.

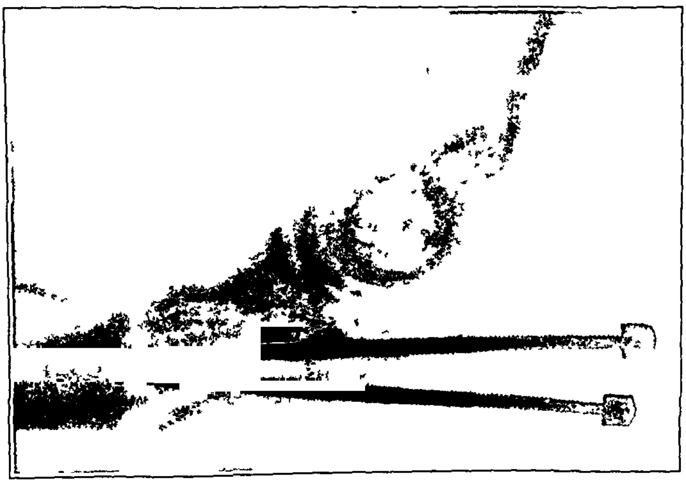

FIG. 2-A

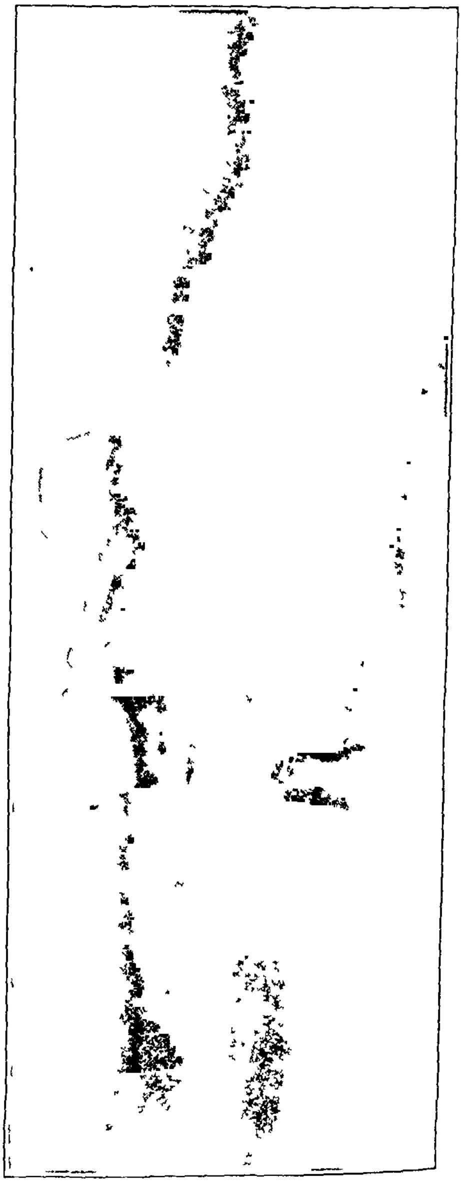

FIG. 2-B

Lateral and anteroposterior roentgenograms of the same fracture eight weeks after fixation.

of a special design, introduced through puncture wounds posterior to the elbow. This type of screw has been previously described[1] and Figures 2-A and 2-B illustrate its use. The protruding head and proximal portion of the shaft of the screw facilitate subsequent removal (Fig. 3), which has always been done without discomfort to the patient and without anaesthesia. Reduction and initial fixation can be accomplished under local or general anaesthesia.

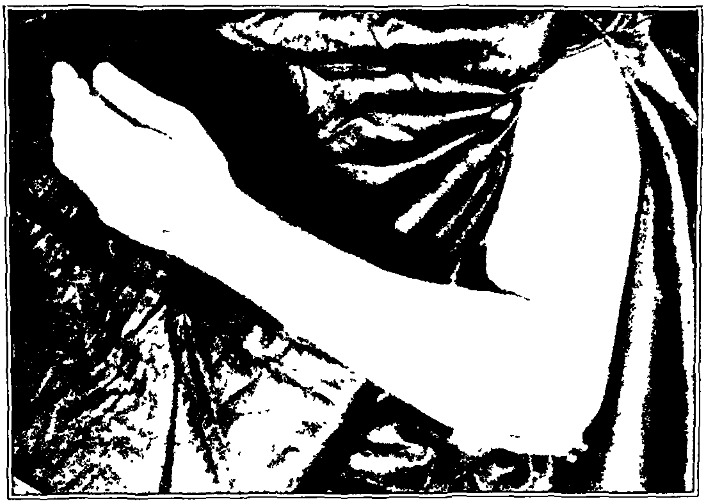

FIG. 3

Maximum of flexion obtainable in the same case ten days following fixation.

MacAusland has described a similar method, differing only in that the screw is shorter and is entirely buried beneath the skin at open operation. Rush and Rush have also utilized the principle of longitudinal-pin internal splintage in extensively comminuted fractures of the upper half of the ulna. Their pin is a modification of the Steinmann type, constructed of stainless steel, with the proximal end flattened on three sides to fit the clamp of a hand drill.

Patients do not suffer postoperative pain following fixation, so that extensive active motion is possible within a few days. Our patients have usually obtained 50 per cent. of normal range of elbow motion in four weeks. At the end of eight weeks, all but one of the screws are removed. The last screw is left in place for an additional four weeks.

In eleven cases of transverse fracture of the olecranon, active motion averaged 105 degrees at four weeks, 135 degrees at eight weeks, and all except two patients had full motion at twelve weeks. This rate of recovery of active motion is about twice that following open operation with internal wiring or other suture of the fragments. Eight patients returned to work eight weeks or less after injury. In one instance, that of a person with secretarial duties, active work was resumed the day after fixation. The other two patients were compensation cases and did not desire to resume work until the arm was "normal". As far as could be judged from the roentgenograms, osseous union was present in every case within eight weeks. The only other method which approximates this quick recovery is that of excision of the proximal fragment, described by Wainwright.

The twelfth patient was admitted, following non-union by cast treatment. After the fracture surfaces had been freshened at open exposure, fixation by the same technique was employed. Complete range of motion, delayed about six weeks, was finally achieved.

We have also utilized these screws for fixation of complete acromioclavicular separation, for fixation of the sternoclavicular articulation in delayed open replacement at this joint, and in certain depressed fractures of the tibial condyles.

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MULTIPLE RIB FRACTURES TREATED WITH A DRINKER RESPIRATOR

A Case Report

BY LIEUTENANT KRISTOFER HAGEN

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In a recent critical review of war injuries of the chest, Edwards attaches a most unfavorable prognosis to that type of non-penetrating chest injury known as the "stove-in chest". After reviewing 1132 cases of chest injuries, Elkin and Cooper agree that the prognosis in this particular injury is poor. In the 'stove-in chest" most of the ribs are fractured bilaterally and the chest wall is rendered unstable. The causes of such an injury in war are various, whereas in civilian life, the most frequent cause is an automobile accident.[5]

PHYSIOLOGICAL ASPECTS

The physiological disturbances caused by this injury are many and profound. Shock is usually present, sometimes due to intrathoracic hemorrhage from a ruptured intercostal vessel, more often due to severe pain or disturbed chest physiology. Respiration is greatly impaired[7], and a condition resembling a large open pneumothorax is produced. Paradoxical respiration develops, as a whole segment of the chest wall is depressed during inspiration and forced outward during expiration. The dynamics of circulation are also affected. Normally the intrathoracic pressure is negative, fluctuating from -2.5 to -6 millimeters of mercury pressure during the respiratory cycle. The venous inflow to the heart via the thin-walled great veins of the chest and the auricles is assisted by the pumping action of these fluctuations in intrathoracic pressure. When the chest suffers a "stove-in" injury, much of the fluctuating negative intrathoracic pressure is lost. Cardiac circulation may be rapidly embarrassed. Another complication, observed by Key and Conwell, is paralytic ileus, associated with reflex spasm of the abdominal muscles.

TREATMENT

The principal considerations in the treatment of all chest injuries are: (1) the treatment of shock and hemorrhage, (2) the early restoration of normal cardiorespiratory function, and (3) the treatment of complications or sequelae. To accomplish the first and third of these purposes in the case of the "stove-in chest" involves routine surgical technique. One exception, perhaps, is that in treating shock a comfortable propped-up position or sitting posture is preferred to the usual Trendelenburg position. The difficulty in accomplishing the second purpose, however, may not be so easily solved, as may be reflected in the variety of procedures recommended.

Many authors [1, 4, 5, 6, 15] suggest immediate immobilization of the chest wall with adhesive strapping or swathing, applied from below upward, with the chest in full expiration, supplemented with oxygen by the most convenient method and other supportive measures. Roberts and Tubbs emphasize the danger of aggravating the patient's condition by early strapping of severe chest injuries of this type during the initial period of shock. They advocate rolling the patient onto the affected side until shock is controlled; they find delayed adhesive strapping surprisingly effective, even when as many as eleven ribs are fractured on one side. According to Blades, one adhesive strip encircling the chest at the level of the costal margins anteriorly is just as effective as multiple strips. On the other hand, Key and Conwell, and Speed advise limiting the strapping technique to cases in which ribs below the fourth rib are fractured; they consider strapping unwise in more extensive multiple rib fractures. Others [7, 9] favor infiltration of the affected

intercostal nerves with procaine. Bohrer infiltrates the intercostal nerves and considers strapping of any "severely crushed" chest unwise, adhering rather to bed rest, sedation, oxygen, and other conservative measures.

Surgical intervention in severe cases to elevate depressed rib fragments and to immobilize the fractures with sutures or wire is preferred by some [7, 13]. A method of applying hook traction to the sternum at the level of the third interspace has been suggested [10], as has traction by sterile towel clips or wires applied directly to the involved ribs [17].

Gray suggests that, if tight dressings, light sandbags, or similar measures do not immobilize the chest sufficiently to permit normal breathing, a respirator may be used "so that the respiratory act may be controlled". Watson-Jones also finds the respirator useful in severe cases.

The following case of severe crushing injury to the chest is reported, because of the dramatic improvement produced in the patient's condition by the use of a Drinker respirator, and because of the interesting physiological principles involved.

CASE REPORT

W. S., a Cherokee Indian, forty-six years of age, was admitted to the William J. Seymour Hospital, Eloise, Michigan, on July 18, 1943, at 8:45 in the evening, one hour after having been involved in an automobile accident. His car had overturned and a 285-pound passenger had fallen directly onto his chest. He was given a quarter of a grain of morphine sulfate at the scene of the accident by a physician. Upon admission to the Hospital, he complained of difficulty in breathing and pain in the chest, but felt well enough to request his discharge. While still in the admitting room, however, his symptoms became rapidly worse and he consented to hospitalization.

Physical examination revealed a short, stocky, moderately obese male Indian of middle age in respiratory distress and with moderate cyanosis. Rectal temperature was 100.6 degrees, the pulse 120, the respiratory rate 48, and the blood pressure 120/82. There was a small but deep puncture wound of the right arm and a long superficial abrasion of the skin along the right posterior thoracic wall. The wall of the chest moved paradoxically with respirations, especially on the left side. The entire thoracic cage was somewhat immobilized by spasm of the intercostal muscles, and respiratory effort was chiefly abdominal. Bony crepitus and marked tenderness were elicited on both sides of the chest, most marked on the left. The patient could not tolerate percussion of the chest. Auscultation was unsatisfactory, but revealed some coarse rhonchi on the left and sounds suggesting the presence of fluid on the right. The heart sounds were normal. The abdomen was slightly distended, but otherwise normal.

The patient was given 1500 units of tetanus antitoxin. The puncture wound of the arm was treated and he was put to bed. Two hours after admission, he had become extremely dyspneic, cyanotic, restless, and uncooperative, and had had periods of semiconsciousness. Physical examination and fluoroscopy revealed the probable presence of fluid in the left pleural cavity, but a thoracentesis yielded no fluid. He was placed in an oxygen tent, which was adjusted to provide eight to ten liters of oxygen per minute, and was given one grain of codeine sulfate hypodermically. At three in the morning he was rational and cooperative, but continued to be dyspneic and moderately cyanotic.

Roentgenograms of the chest taken later in the morning (Fig. 1) showed fractures of the second to the eleventh ribs in the right posterior axillary line, the fourth rib being fractured in two places. There were also fractures of the second to the twelfth ribs on the left, with over-riding of the second, fourth, and fifth rib fragments. Gaseous distention of the stomach was noted.

Wangensteen suction was instituted to relieve the upward pressure of the dilated stomach, but despite this measure and the continued increased administration of oxygen, the patient became steadily more dyspneic and cyanotic. He complained of severe interscapular pain. His temperature remained elevated (Fig. 2), the blood pressure rose rapidly to 228/130, the pulse to 132, and the respiratory rate to 64 per minute. The advisability of some immediate operative procedure was considered, but abandoned in favor of placing the patient in an available Drinker respirator. This was accordingly done at 8:30 on the evening of July 19, about twenty-four hours after the injury. The treatment with oxygen and the Wangensteen suction was continued. The respirator was adjusted to provide a *negative* pressure of 20 millimeters of mercury intermittently at a rate of 36 cycles per minute. The valves were carefully adjusted to *avoid positive pressure* inasmuch as it was felt that the patient needed only expansion of the chest by artificial means. Within an hour after being placed in the respirator the patient's color and general condition showed marked improvement. By the next day his blood pressure had decreased to 182/102 and his pulse to 100 per minute. His temperature rose to 102 degrees orally. He was able to do without the oxygen tent and to have the rate of the respirator reduced to 28 per minute (Fig. 2). Two days later he was afebrile, had a blood pressure of 136/80, pulse rate of 80 to 100 per minute, and felt comfortable with the respirator set at 21 per minute

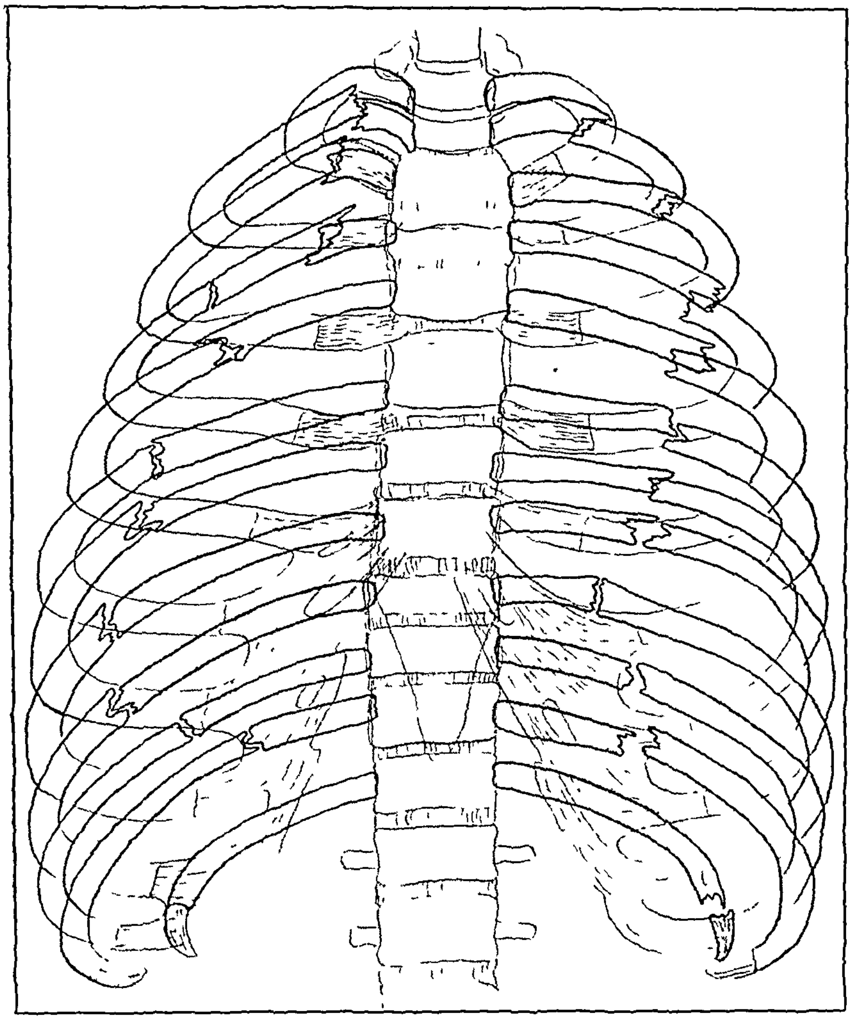

FIG. 1
Diagram of rib fractures adapted from x-rays.

On July 26, after one week in the respirator, he was removed for several hours, but as it was noted that his respirations, pulse, and blood pressure began to rise promptly (Fig. 2), he was returned to the respirator and kept there constantly for a total of ten days, when a schedule of gradually increasing periods of time outside of the respirator was instituted. By August 7, three weeks after the injury, he could breathe without the aid of the respirator. Chest-expansion exercises were instituted and he was discharged in fair condition on August 27. At the time of discharge roentgenograms showed early callus formation at the sites of the fractures, thickening of the left pleura, and some interlobar pleurisy on the right.

He was last seen in the Out-Patient Department on March 31, 1944, and he stated that he felt very well and had been able to carry on full-time work as a metal polisher since October 1943. He weighed 180 pounds, had a temperature of 98.6 degrees, a pulse rate of 76, respiratory rate of 20, and blood pressure of 186/100. Chest expansion was two inches at the level of the fifth rib. Vital capacity was 2850 cubic centimeters in the standing position and 2600 cubic centimeters in the sitting position, which was calculated to be about 70 per cent. of normal for his height and weight. Roentgenograms showed good bony union of all fractured ribs, though there was persistent over-riding of the fractures of the second, third, fourth, and fifth ribs on the left. The lung areas were clear.

COMMENT

This case presents several very interesting features. Unlike most persons similarly injured, the patient never seemed to be in shock. On the contrary, he did develop a hypertension during the first few hours after injury. A possible explanation for the hypertension is the profound retardation of circulation produced by the loss of normal, fluctuating, negative intrathoracic pressure.

The slowed circulation must have involved also the renal circulation and produced a renal ischaemia with a consequent hypertension, comparable to the Goldblatt mechanism. The hypertension was quickly relieved when the cardiorespiratory function was restored to normal by the respirator.

An interesting and perplexing finding was observed months later, however, when the patient, apparently fully recovered from the injury, was found to have a moderate hypertension. Of course, this may be unrelated to the injury, inasmuch as the patient was of the habitus and age group in which hypertension most often develops. The finding should not be overlooked. Could it be due to delayed kidney damage?

The patient improved so dramatically after being placed in the Drinker respirator that the following conclusions were reached:

1. Wherever a Drinker respirator is available, it is a much *simpler treatment to apply* than other procedures used to accomplish stabilization of the thoracic wall.

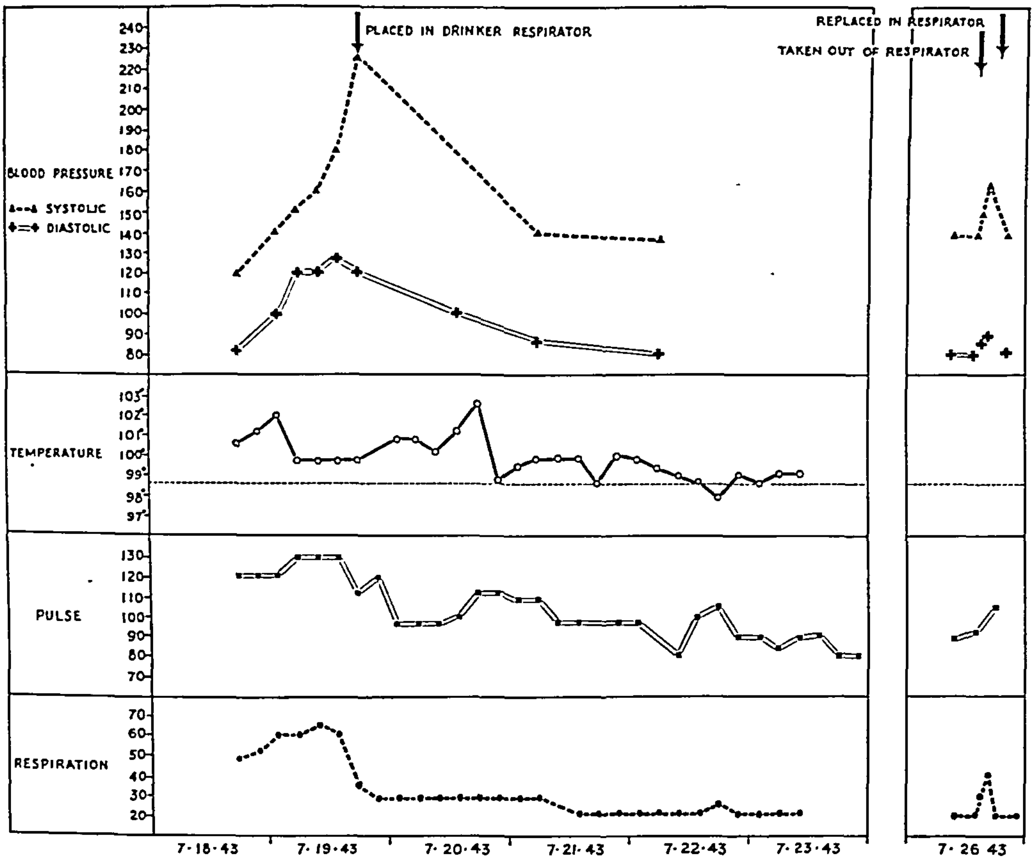

Fig. 2

Clinical Chart.

2. It *avoids the obvious risks of surgery* in patients who are already critically ill, and the danger of infection associated with traction hooks in sternum or ribs.

3. It exerts a *gentle, non-mechanical expanding effect* on a thoracic cage which is already compressed and is thus obviously superior to any binding or taping measures, which tend to compress the chest further.

Obviously one cannot generalize and say that the respirator is the only treatment for the "stove-in chest" injury. Every patient with a seriously injured chest requires individual consideration, but it would appear that the use of the Drinker respirator, wherever available, deserves more consideration than it has heretofore received in the treatment of this type of injury.

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A RETROSPECTIVE COMMENTARY ON THE CAMPAIGN FOR THE ESTABLISHMENT OF THE POSITIVE STANDARD OF TREATMENT FOR FRACTURE OF THE NECK OF THE FEMUR

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Positive treatment of fractures at the hip was made practicable by the substitution of natural for artificial mechanics. For since the neck of the femur projects laterally from the shaft, splinting and traction can at best appose displaced fragments only in a lateral and, therefore, insecure relation.

The inadequacy of the means at command to provide the stability essential to repair was clearly demonstrated by Sir Astley Cooper early in the last century. He contended that since it was impossible, even for a few hours, to preserve exact apposition of the fragments, the surgeon should not be held responsible for a result over which he could have so little control.

His pronouncement established the *negative* standard, which determined the character of conventional practice for a hundred years. Surgeons long maintained that restoration of form and function was rarely to be attempted or even sought, and that the first indication was to save life; the second to secure union; the third to correct or diminish displacements.

The first of these results could be attained by propping the patient up in bed with the limb between sandbags. After a month the patient would be encouraged to use the limb as much as possible, since union was not aimed at. Union seemed to be dependent on adhesion or impaction of the fragments, and actual treatment was usually limited to making only as much reduction of the deformity as could be expected from moderate traction and immobilization by cushions or by a fixed dressing.[4] It was taken for granted by all that a broken hip entailed permanent disability, and in many cases death.[12]

No matter whether the fracture took place within or external to the capsule, or whether it united by ligament or by bone, shortening of the limb and lameness were considered to be inevitable results. One writer even held that, "If he [the patient] escapes with his life, he has to be contented with loss of function, loss of symmetry and equipoise, and is often obliged to go about crippled".[2]

The character of the disability is illustrated by a report on the final results in eighteen cases that had received hospital care by extension in bed without direct fixation. Five of the patients had never attempted to walk; eight used two crutches in locomotion; one used a crutch and a cane; one used two canes; two used a cane; and one wore a high shoe, but walked without support.[21]

This introduction has been drawn from representative sources in order to present fairly the background on which the anatomical method, as the exponent of surgical principles and, therefore, of radical reform, was projected. It will also serve as a point of departure from which to estimate progress toward the establishment of the *positive* standard.

The inception of the anatomical method was coincident with the identification of fracture of the hip in childhood, an injury unknown to authority and, therefore, beyond its jurisdiction. The typical history of such a case was that of a child who had fallen from a fire escape. The fracture was not recognized, but, as it was incomplete, repair had followed. Months later the child was brought to the hospital for a persistent and increasing limp, supposed to indicate hip disease. At this time (1890) the x-ray was not available for diagnosis, but the elevation of the trochanter, the outward rotation of the limb, and the evident limitation of abduction by bony contact, indicated a downward and backward displacement of the femoral neck, afterward called coxa vara.

This analysis of the disability was enlightening, since it demonstrated that the chief factor in the limp, the inevitable sequence of the fracture in adult life, was not shortening of the limb, to which it had been attributed, but restriction of abduction. It was evident, therefore, that restoration of the normal relations of the hip joint was the only remedy.

This was accomplished indirectly by an osteotomy at the base of the trochanter, so that by abducting the limb and rotating it inward, the shaft was brought into proper relation to the neck; for under normal conditions, the position of the head would require a corresponding abduction and inward rotation of the shaft.

A plaster spica was then applied and retained until union was complete. Therefore, when the limb was brought to the mid-line, in apposition to its fellow, the angle of the neck was automatically restored, and functional cure was established.

The success of this first essay in reconstructive mechanics clearly indicated that, if one had the opportunity to treat the fracture in the plastic stage, the deformity might be corrected directly by the same manoeuvre,—namely, by forcible adjustment of the shaft to the articulating fragment fixed in the acetabulum.

On further investigation of the mechanism of the joint, it appeared that the anatomical method would be equally effective for the complete or typical fracture, long considered the keystone of the negative standard. If the fragments were brought into the same plane by traction on the limb and inward rotation, full abduction by tension on the capsule would adjust them; and the security of end-to-end apposition would be supplemented by the impingement of the base of the neck on the rim of the acetabulum. Furthermore, in this attitude, there would be complete suppression of muscle action, an agent of deformity that Sir Astley Cooper had found impossible to control.

This experience clearly indicated that the primary essential of functional repair in all types of fracture at the hip was the restoration and maintenance of the femoral angle. To emphasize this conclusion, the method by which it was accomplished was called the "abduction treatment".

Since it was evident that, from the mechanical standpoint, a method effective in

childhood would be equally so in adult age, a new field of therapeutic endeavor was opened. At the outset it was encouraging to note that the established inhibitions to positive treatment were in the nature of a defense reaction to therapeutic inadequacy The typical patient of the textbooks was aged and feeble, but the vigorous subject fared no better as far as technical treatment was concerned. It was assumed that the complete medial fracture was practically incapable of repair, but its recuperative capacity had never been tested by opportunity. It was assumed that the restraint required for positive treatment of the fracture would endanger life. It appeared, however, that in fatal cases, the patient usually survived for several weeks, to die from "exhaustion", of which the chief contributing factors were hypostatic congestion of the lungs and infected bed sores. The mobility of the plaster spica, and the security of the anatomical splinting suggested effective remedies against these complications. The patient was placed on an inclined plane by raising the head of the bed one foot or more, and was turned at intervals from side to side and completely over to the ventral position. Furthermore, the security of the support permitted transportation to the open air or elsewhere, with the inspiriting prospect of eventual recovery, thus providing a moral as well as a physical prophylactic for the conventional exhaustion.

Since the object of positive treatment was to restore function, the initial opportunity for its attainment was supplemented by equally adequate after-care. It was recognized that repair of the medial fracture, since it was an interstitial process unaided by external callus, must be slow and precarious, dependent upon rest, uninterrupted and prolonged. Furthermore, because of its exposed position, the resumption of activity should be strictly regulated to the stability of repair. During the recuperative period, the first concern should be the maintenance of the range of abduction by routine manual "stretching" outward to the primary position until voluntary control had been established. Finally, the patient should be trained in the equal gait, since the test of success was no longer "to save life" nor "to get union" but a symmetrical gait.

Thus it will appear that the abduction treatment was developed by successive steps, in logical sequence, upon a secure foundation, and followed to its legitimate conclusion.

Established teaching offered no incentive to efficiency and, therefore, no penalty for incompetence and neglect. Naturally, the abduction treatment, the exponent of the positive standard and consequently of radical reform, made slow progress against the weight of authority, inertia, and technical unpreparedness to meet its requirements. However, in the lapse of years it has come into general use, and experience has amply demonstrated its comprehensive practicability.

Of 441 cases of medial fracture treated by this method, 126 of the patients were over seventy, and fifty-seven were over eighty years of age, yet the death rate was only 7 per cent.

As to the capacity of the medial fracture for repair, a competent observer concludes that union should be attained in 65 per cent. of the older class, and in 90 per cent. of those less than sixty years of age.[7]

Yet in a group of seventeen patients over seventy, union occurred in 78 per cent.[14]

Formerly, as has been noted, a sharp distinction was made between the intracapsular fracture, in which the patient was the first consideration, and the extracapsular type for which protective treatment might be of service in promoting repair.

The relative frequency of the two forms is indicated by a report of 264 cases treated by the abduction method: 172 were intracapsular with union in 67.5 per cent.; ninety-two were extracapsular with union and good function in all,—approximately 80 per cent. of the group. The mortality rate was 6 per cent.[9]

Now that all types of the injury are treated by the same method and with the same purpose, namely the restoration of normal locomotion, the fracture may be considered as an entity. A direct comparison with the nailing method may serve to clarify what

appears to be a general misapprehension of the relation of one method to the other as representative of the positive standard.

Nailing the fracture was introduced during the last century as the only means of fixing the fragments.[10] The method has undergone several modifications in technique in recent years.[1, 8, 13] Its most attractive feature is the relative freedom from restraint that the security of the internal splint permits.

From reports on the nailing method, one might infer that secure fixation of the fragments assures a fairly free and painless range of controlled motion. Actually, since the joint is involved in the process of repair, it is sensitive to unguarded movement. Sympathetic muscular protection restricts the voluntary range, and there is a persistent tendency toward the protective attitude of flexion and adduction, a tendency that would be favored by locomotion and confirmed by the sitting position in the wheel chair. Thus the abduction treatment has become the representative of conservatism by maintaining rest during the initial stage of repair as the essential factor in the restoration of function.

The nailing method can qualify as an alternative to the abduction treatment only in a restricted sense. It is not adapted to fractures at the base, since the cancellous structure of this region cannot assure security for the nail, and because the trochanter may be involved in the injury. In this type of fracture, the capacity for repair is adequate, and there is even a tendency to callus formation to the extent of embarrassing function. Thus motion is contra-indicated, even if the stability of the internal splint were assured.

For these fractures, the indications for treatment should be evident,—namely, to restore the femoral angle and to maintain the attitude of abduction. For this purpose the mechanical advantages of the abduction method should be obvious.

Considered as an alternative to the abduction treatment, there are intrinsic and incidental drawbacks to the nailing method that must be reckoned with. A certain shortening of the femoral neck during repair is not unusual, and a number of cases have been reported in which spontaneous extrusion of the nail has permitted union which otherwise would have been prevented.

Partial necrosis of the head of the femur may occur after union, to which functional activity may have been a predisposing factor. The same inference applies to secondary arthritis. Depression of the femoral neck to the degree of embarrassing function is another mishap which must be attributed to premature weight-bearing.

The most illuminating paper bearing upon the question at issue, that has come to my notice, is an analysis of the final results in seventy-five cases of intracapsular fracture treated by the Hey Groves method of pinning in the Bristol Fracture Service.[6] The fragments were adjusted by manipulation under x-ray supervision, while the limb was supported in an attitude of 15 degrees of abduction and slight inward rotation by a seated nurse who exerted slight traction on the flexed leg by leaning backward. Five to seven roentgenograms were taken to assure the adjustment of the fragments and the proper direction and depth of insertion of the nail. Movement of the limb within a few days was encouraged. Direct weight-bearing was not officially sanctioned for three months, but locomotion on crutches was resumed at a much earlier date.

Fifty-two of the seventy-five patients were personally examined. Seventeen were dead and six were not available for tabulation. The results were classed as satisfactory in 50.7 per cent. Failure was attributed to defective technique in seven cases and to suppuration in three. In two cases the neck was shortened, but spontaneous extrusion of the nail had permitted repair. In four instances there was necrosis of the head of the femur after union of the fragments.

As to function, it was stated that from 80 per cent. to 100 per cent. of motion was retained, but as there was a certain degree of varus or valgus deformity in three cases, complete restriction of abduction in one, and of inward rotation in another, it is evident that success did not imply a symmetrical gait.

Accepting this report as fairly representing the nailing method as a routine and independent procedure in competent hands, it may be suggested that the failures attributed to defective technique might have been lessened, if the anatomical method had been utilized to adjust the fragments, which in full abduction and extension lie in a horizontal plane, fixed end-to-end by capsular tension against the resistant pelvis. Thus they should not be displaced or jarred apart by the impact of the nail. Relatively speaking, the whole procedure may be completed in a few minutes, as contrasted with the prolonged manipulation required for tentative adjustment. On this point I can speak from personal experience. Many years ago I made a brief trial in spiking, only for the purpose of assuring greater security, but I soon discarded the practice as unnecessary.[17]

It may be assumed that the functional results might have been better if the resumption of activity had been adapted to the resistance of stable repair, rather than to what Brailsford refers to as the false sense of security which the nail gives.

This analysis seems to support the conclusion that the nailing method should be classed as a complement to the abduction treatment, in the sense that anatomical mechanics should be utilized to adjust the fragments. It is of value in a special type of fracture, as an internal splint in relieving the patient from the restraint of a comprehensive support. But it must be remembered that its use as a prop for weight-bearing and as a pivot for enforced movement during the critical period of repair is a concession to the patient at the expense of the functional result.

The final step in the expanding scope of anatomical mechanics was in the treatment of ununited fracture at the hip, a common, crippling, and often a painful and progressive disability. The loss of resistance to weight-bearing induced friction and disintegration of the fragments, upward displacement of the shaft, and the deformity incidental to persistent flexion and adduction of the limb.

The problem in treatment, therefore, was to restore stability in weight-bearing and to assure the maintenance of abduction, essential to serviceable locomotion. This was accomplished by the reconstruction operation.[18] The trochanter with its attached muscles was separated from the shaft in the line of the neck, thus providing a sufficient area of bearing surface. The head of the femur was removed, and the improvised neck securely implanted in the acetabulum by abducting the limb to the required degree. The trochanter was then drawn down as far as its attachments would permit, and implanted on the outer border of the femur. A plaster spica was applied, holding the limb in approximately twenty degrees of abduction and full extension. Eventually this was replaced by a short spica, and locomotion was resumed. When the security of the transplanted trochanter was assured, the support was removed and a routine of manual stretching of the limb outward to its original position was instituted, and continued until voluntary control had been established.

The distinctive advantage of the reconstruction operation in the class of cases for which it was designed was that, since it was based on sound mechanics, a satisfactory result might be assured in a definite time, as contrasted with procedures in which it was dependent upon the uncertainties of repair.

The principles of the reconstruction operation have been applied with success in a number of different conditions resulting from injury or disease,[20] and it should be a preliminary to all forms of arthoplastic procedures in which shortening of the femoral neck and contact of the trochanter with the acetabular rim limits the range of motion essential to satisfactory locomotion.

The reconstruction operation in completing the therapeutic control of this refractory fracture brought the campaign for the establishment of the positive standard to a successful conclusion. As no claim has ever been made for a share in the inception and development of the method by which it was accomplished, it would seem to qualify as a personal contribution to surgical progress.

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ERNEST WILLIAM HEY GROVES, M.D., M.S., F.R.C.S.

1872–1944

In the passing of Hey Groves, The British Orthopaedic Association has lost one of its most distinguished members and a former President. His name is known the world over as that of a pioneer who has clearly left his mark, not only upon orthopaedic surgery, but directly and indirectly upon the art and science of surgery in general.

Hey Groves was the son of an English civil engineer, Edward Kennaway Groves, and was born in India in 1872. At the age of three, when his father retired, the family settled in Bristol.

His medical education was received at St. Bartholomew's Hospital, London, where, having taken the degree of Bachelor of Science, while still a student, he started his teaching career as a demonstrator ["instructor" in the United States] of biology. This experience stood him in good stead, for he later became an outstanding teacher of surgery. Following his graduation in 1895, his first interests were in obstetrics and, after experience in different parts of England and a period of study at Tübingen, he settled in general practice in one of the outer Bristol suburbs. But he did not stay long in general practice. His search for surgical knowledge and experience was insatiable.

In 1896 he married Miss Frederica Anderson, who had been a nurse at St. Bartholomew's, and together they made their home into a private hospital. Here, with the help and encouragement of his wife, Hey Groves established his reputation as a surgeon. To his students he used to say that this episode in his life had its darker side, for tales were spread abroad that "Butcher Groves lured women into his home, operated upon them, and would not remove their stitches until they had paid their money". In spite of such petty nuisances, he was indefatigable, for, in the midst of his busy practice, he was able to attain high academic honors.

In 1905, having taken the Fellowship of the Royal College of Surgeons of England and the degree of Master of Surgery of London University, he was elected to the staff of the Bristol General Hospital. While thus engaged in surgery, he was still able to work as senior demonstrator of anatomy in Bristol University. He never deserted general surgery, but his mind soon tended to concentrate upon the mechanics of bone and joint surgery. He was indeed most ingenious and skillful, and "Hey Groves" splints and appliances became a byword. Indeed his early work anticipated much that followed in the field of orthopaedic surgery. Before the days of the Smith-Petersen nail, he fashioned pins from beef bone and horns for use in fractures of the neck of the femur. In 1913, he described transfixion pins which, passing through fragments, were fixed to external bars, thus with Lambotte anticipating Roger Anderson, Haynes, and others who later perfected this principle. These pins were again used by him in the treatment of gunshot injuries of bones; he wrote a primer on this subject in 1915. During the War of 1914–1918, he served in the Royal Army Medical Corps, and was sent to Egypt in charge of the surgical division of a general hospital. Illustrating his resourcefulness, it is related that, on setting out for Alexandria with other R.A.M.C. officers, he found that none could go aboard ship unless properly dressed in spurs; whereupon he managed to acquire a rusty pair at a marine store, and, having himself embarked, tossed them ashore repeatedly for the use of each of his colleagues in turn.

On November 28, 1917, he was one of that small group of surgeons who met together at dinner at the Café Royal in London to consider what steps should be taken to found an association of British orthopaedic surgeons. At that time Hey Groves did not regard himself as an orthopaedic surgeon in the accepted sense of the term; but, at the invitation of Robert Jones, he had already entered the fold by taking surgical charge of the Military Orthopaedic Centre at Bristol. His intrusion into orthopaedic surgery was viewed by certain purists of the older school with considerable misgiving, and, by a narrow doctrinaire interpretation of what constituted a "real" orthopaedic surgeon in the year 1917, his name was omitted from the list of eighteen surgeons invited to become foundation members of the new Association. It was characteristic of the man that he showed no open resentment at this most unfortunate action. It was not long before the Association made amends by sending a special invitation to Hey Groves to join in the capacity of an original member. From that time on, he became a loyal and powerful advocate of the cause of orthopaedic surgery; and, during the earlier years of the Association, this small specialist body gained prestige from the fact that one of its most distinguished active members held a University Chair of Surgery, was the Editorial Secretary of *The British Journal of Surgery* and later became a Vice-President of the Royal College of Surgeons. It was clearly fitting that Hey Groves should in due course be chosen as President of The British Orthopaedic Association, and his second year in that office (1929) was notable in the annals of the society as the occasion when a strong contingent of The American Orthopaedic Association came to London to take part in a joint meeting with their British colleagues. The following year Hey Groves became President of the Association of Sur-

E. W. HEY GROVES

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;eons of Great Britain and Ireland, thus attaining to the dual honor which Robert Jones had previously .chieved, and thereby forging another link between general and special surgery.

The British Orthopaedic Association is now, by common consent, the most vigorous of the special Asso-·iations in Great Britain. It has a large and ever-growing membership, but there has been no schism. Or-hopaedic surgery remains within the fold of surgery as a whole, and the tradition of unity founded by Robert [ones and fostered by Hey Groves still endures.

At Bristol, Hey Groves had been promoted to the Chair of Surgery in 1922. An old student writes: "He ıad a vivid character, full of imagination and energy; he was an excellent teacher who brought a great sense of ıumor to his well attended ward rounds and operations. He was naturally very popular among the stu-lents; for, youthful himself, he was very fond of young company and always enjoyed a party, particularly lancing. Not infrequently his students, staff, and ward sisters were invited to join him—he was so charm-ng." Some of these students had other reasons to be grateful, for not a few keen men were helped financially hrough difficult periods of their student life and the following days.

As a writer, Hey Groves was prolific; several standard textbooks on surgery for students and nurses came rom his pen. For the practising surgeon, his concern was no less great, particularly his desire to advance the treatment of fractures and operative technique. "The Modern Treatment of Fractures", written in 1916, was followed by many authoritative articles on these themes, and in 1935 he published his translation of Lorenz Bohler's work, of which he was a wholehearted supporter. In his foreword, Hey Groves emphasized the fundamental principles which Bohler had demonstrated: "the necessity for unity of control, loyal and efficient team work, accurate knowledge of the after-results, and meticulous attention to detail".

Throughout his life, both in surgical practice and in teaching, his mind was alert to the needs of the "everyday" problem, the thorough teaching of the student and younger surgeon in groundwork, and the simplification of methods for the safety of the patient. No better example of this can be found than in that product of his later period, the "Hey Groves Introducer" for the Smith-Petersen nail, which one of his followers has described as "making a very difficult operation simple".

In all this, sufficient would be found to place the name of Hey Groves high in the history of surgery during the past fifty years. In addition, however, we must note the special part he has played in scientific journalism, and in the advance of surgery through the distinguished *British Journal of Surgery*, with the origin of which he was so closely concerned, and whose destinies he so largely directed as editor for twenty-eight years. In 1941, when he was forced to retire, owing to a period of ill health, aggravated by enemy action, the Journal was able to say:

"During all this time the services of our Editor have been remarkable and steadfast and his robust honesty of purpose and tireless work have served the Journal well. A wide knowledge of world literature and foreign travel have given Groves a breadth of outlook which has been of great value. Our present position entitles us to claim that we rank very high among the leading surgical journals of the world, and it is not too much to say that this enviable position is very largely due, not only to the work, but to the outlook and the sustained interest of our first Editor."

Certain it is that *The British Journal of Surgery* has set a very high standard, not only in its format and technical production, but in the care which obviously for so long has been spent upon its editing. In that Journal's first twenty-eight volumes, will be found for future readers a worthy monument to Hey Groves.

SIR HENRY GAUVAIN, M.D., M.CHIR. (CANTAB.), M.D. (HON.) MELB., F.R.C.S.

1878–1945

In the year 1908, there was founded at Alton in the English County of Hampshire, the Lord Mayor Treloar Cripples' Hospital. The founder, Sir William Treloar, a philanthropic man of business, chose as Resident Medical Officer a young man, thirty years of age, who had only recently completed his house appointments at St. Bartholomew's Hospital, London. Sir William planned his hospital to care for the crippled children of London, whose need had so greatly impressed him. The plans were laid with care, and have borne abundant fruit in the fine modern orthopaedic hospital which now bears his name, caring for a far wider community than was dreamed of by its founder. That such development and expansion proved possible can in large measure be attributed to the vision, energy, and enthusiasm of that young man of thirty, who later became Sir Henry Gauvain, the Hospital's Medical Superintendent, and who for thirty-seven years labored to develop and expand the work of the Hospital, so that it has acquired an international reputation.

It is difficult now to realize the indifference and lack of interest in crippling conditions—particularly surgical tuberculosis—that existed forty years ago. Gauvain, from the first, made surgical tuberculosis his especial study, and in the course of a few years materially altered the pessimistic attitude characteristic of those days toward all forms of bone and joint infection. Deliberate and planned conservative treatment of surgical tuberculosis was scarcely practised in England at that time. Indicative of the apathy with which Gauvain had to contend was the comment of a distinguished consultant member of the Medical Board which Sir William Treloar had appointed to guide him in developing the Hospital, who said of Gauvain's request for provision of a sterilizing plant: "Of what use are sterile dressings for cripples?"

Gauvain, born in Alderney of an old Channel Island family, had early acquired a love and appreciation of the value of the sun and the sea. A visit to Berck-sur-Mer, where the conservative treatment of surgical tuberculosis had already been practised for many years, quickly led Gauvain to realize the importance of the open air and the sun in the treatment of the disease.

From the first, therefore, Gauvain stressed, in articles and to the many students and medical men who soon began to come to Alton, that the surgical tuberculous lesion was but a local manifestation of a general disease, and that no form of local treatment could be successful unless it were accompanied by "all possible measures to improve the patient's general health and increase his powers of resistance to tuberculous disease". Gauvain was a man of vision and originality, and he determined to interpret his principle of full and active conservative treatment of the patient as a whole in its widest and most complete sense.

He studied hospital planning and persuaded the Trustees of the Hospital to build at Alton a hospital which is a model of hospital design for the open-air treatment of children, with the most complete surgical facilities. Land was acquired at Hayling Island for a seaside branch, so designed that bed as well as ambulant patients could benefit by sea-bathing as a form of treatment.

SIR HENRY GAUVAIN

Gauvain realized early that no plan of general treatment for a chronic disease in childhood could be ade-
:ate, which did not also cater to the mind. An experimental hospital school—the first of its kind in Eng-
›d—was sanctioned by the Board of Education in 1912. Lloyd George, then President of the Board of
lucation, was so impressed with the importance of the work that he decided that grants should be given to
tend this type of education throughout the country.

By 1920, when Gauvain received the honor of knighthood, it is no exaggeration to say that his work had
l to an entirely new outlook on the part of the profession toward the possibilities of the non-operative
:atment of surgical tuberculosis and the prognosis of the disease.

Gauvain did not neglect the local treatment of the tuberculous lesion. He designed a number of splints
d appliances for the fixation of the lesion and the prevention or correction of the deformity. All such
pliances were governed by the principle that "the simpler the appliance employed, the greater the comfort
the patient; and the fewer the complications in the apparatus, the better the result will be". He was re-
onsible for introducing the technique for making light moulded splints of celluloid-impregnated muslin, so
luable for use in tuberculous disease in children. To see him apply and mould a plaster spica to a child
is to realize that for him it had to be artistically satisfying, as well as mechanically efficient.

From Calvé, at Berck-sur-Mer, Gauvain learned the technique of the aspiration of tuberculous abscesses,
rticularly of the psoas abscess. Realizing the value of the method in preventing sinus formation and sec-
dary infection, Gauvain practised and endeavored to popularize the method in England. Surprisingly,
e practice of aspirating psoas abscesses, as opposed to incising the abscesses, was at first strongly opposed
the older surgeons.

As a diagnostician of tuberculous disease, Gauvain acquired a great and well-deserved reputation. In 1918, he first described the sign for the presence of active disease in the hip, which has since become known by his name, and his original description of which deserves repetition:

"If the femur on the affected side be grasped firmly in the region of the condyles, it will be found that the head of the bone may be gently rotated within the acetabulum, either inward or outward, through a varying but often considerable angle. When this movement is checked, but the disease remains active, a further slight sharp rotation is instantly followed by spasmodic muscular contraction, not confined to muscles about the joint but extending to the abdomen and visible in the abdominal muscles, or still more easily demonstrated if the palm of the hand is placed on the abdomen between the iliac spines. Quite a gentle and painless but sharp rotary movement is sufficient to provoke this reflex spasm of the abdominal muscles. Naturally, it would not be attempted where the disease is obviously active, but in just those cases where doubt exists I have found it a sign of the utmost value. With a little practice the sign is easily and safely obtained if the disease is active."

Although Gauvain's early reputation rests upon his crusade for the efficient conservative treatment of tuberculosis, in the widest sense, he was by no means opposed to surgical intervention at the appropriate time. Spine fusion, extra-articular arthrodesis of the hip, and other fixation and stabilizing procedures were practised, but it was always emphasized that these were procedures for the selected case, only to be carried out when the disease was quiescent as a mechanical means of acquiring stability in a part left unstable as the result of disease, and not procedures to be adopted in active disease or to shorten the period of essential conservative treatment.

A gifted speaker with a pleasing and lively manner, Gauvain found many an occasion to spread and emphasize his views, and although his style was perhaps more suited to the popular scientific lecture than to the studious paper, he always gained a ready hearing in both medical and lay audiences; and his manner was such that his addresses were remembered long afterwards. He delivered the Hastings Popular Lecture at the British Medical Association Annual Meetings of 1924 and 1933. In 1926, he went on a lecture tour in the United States of America and in Canada. In 1936, he received the Distinguished Service Gold Key of the American Congress of Physiotherapy. In 1935, he was President of the Tuberculosis and Public Health Section at the British Medical Association meeting held in Australia, and received the honorary degree of Doctor of Medicine from the University of Melbourne. Gauvain also held office as President of the Sections of Diseases of Children, Orthopaedics, and Electrotherapeutics of the Royal Society of Medicine of London.

Gauvain's interest in orthopaedic surgery was in no sense confined to tuberculous conditions, and in recent years he had become particularly interested in poliomyelitis. It had been planned to develop the Seaside Branch of the Treloar Hospital as a center for treatment of paralytic conditions on a large scale. In 1938, Gauvain visited the United States in order to study at first hand the Warm Springs Foundation and other centers where paralytic conditions are especially treated. Plans were again drawn up for a new extension of the work of the Treloar Hospital, and it was one of Gauvain's greatest disappointments that the War has prevented the development of this scheme to provide comprehensive treatment for a range of crippling conditions, for which adequate facilities are not yet available.

As a result of his interest in sunlight as a therapeutic agent, Gauvain became much interested in heliotherapy in all forms and in particular in the treatment of lupus vulgaris. This interest led to the establishment of a plastic unit, primarily for the treatment of scarring left by lupus, but now treating a large range of congenital and acquired defects amenable to plastic surgery.

No appreciation of Sir Henry Gauvain would be complete without some reference to the man himself.

A man of great personal charm, he was able to arouse affection and loyalty in his staff. He was also a man of action and great administrative ability. Always ready to listen, and to discuss suggestions and difficulties with his staff, once a decision was arrived at, it was adhered to and pursued unswervingly.

It was his pride that Treloar Hospital, in which his interest was so very personal, was a happy hospital, and this faculty for keeping his patients happy and contented was to him a very real and essential part of treatment. It was perhaps particularly exemplified by the way in which his essential kindliness and greatness of heart won the affection and secured the contentment of his child and adult patients at his private clinic at Morland Hall, Alton.

An apostle of conservatism in an era which has seen the greater part of the development and elaboration of orthopaedic operative technique, Gauvain's contribution to orthopaedic surgery is perhaps greater than is at present realized.

To those who knew him, he will long remain a friend and mentor whose wisdom, kindliness, and humor will not be forgotten.

PHOTOGRAPH BY BACHRACH

FRED H. ALBEE

1876–1945

In the death of Fred Houdlett Albee on February 15, 1945, in New York City, surgery has lost one of its most outstanding figures. Dr. Albee was known the country over and, at the time of his death, in all probability was one of the best-known orthopaedic surgeons in the world. Although he was the recipient of numerous honors at home and abroad, readers of *The Journal* will not require a list of his attainments. Other readers will find such a list in accurately factual obituaries published elsewhere.* The purpose here is more to recall the characteristics and interests of a friend long known, and to record the sense of loss which his death engenders.

Fred Albee's personality was an unusual one. Endowed with great energy, he never spared himself in devotion to his chosen field of orthopaedic surgery. He was one of those rare individuals who, as the years

* See *The Journal of the American Medical Association*, CXXVII, 477, February 24, 1945.

accumulate, never lose their youthful enthusiasm, but eagerly look for new things which will contribute to man's progress. Although, in a way, Dr. Albee was one of the crusading type, he was always kindly, courteous, and considerate of the opinions of others. He was a great traveler, and his familiar, sturdy figure will be missed at meetings of orthopaedic surgeons.

The founding of the International Society of Orthopaedic Surgery was without doubt due to Dr. Albee's efforts. He was president of many organizations during his career, including The American Orthopaedic Association and The International College of Surgeons.

Contributions to surgical literature made by Dr. Albee were far too numerous to record here, but his early works, "Bone Graft Surgery", published in 1915, and "Orthopaedic and Reconstructional Surgery", issued in 1919, were in their day outstanding. In 1937 appeared "Injuries and Diseases of the Hip", and in 1940 was published "Bone Graft Surgery in Disease, Injury, and Deformity", dedicated to the progress of bone and joint surgery. They are valuable contributions by a seasoned and experienced surgeon. No man contributed more original methods with reference to the use of bone grafts than did Dr. Albee; he was truly a pioneer in that field.

Dr. Albee's interest in the art and science of orthopaedic surgery resulted in his giving much time and energy to rehabilitation of the handicapped. He became particularly active in this work in the course of the War of 1917–1918, when he held the rank of Colonel and was Chief of Staff of General Hospital Number 3, situated at Colonia, New Jersey. It was due to his efforts that there was established, at Colonia, the first rehabilitation center, from which sprang the New Jersey Rehabilitation Commission. In 1940, for his twenty years' service as Chairman of this Commission, he was honored with a testimonial dinner, sponsored by the State Department of Labor and Rehabilitation.

Dr. Albee's family life was a most happy one. His devoted wife shared his many interests. A son, Fred, is just entering the practice of medicine. Closely interwoven with Dr. Albee's family life was the Medical Center at Venice, Florida, which was a project dear to his heart. He spent much time there, living on his estate, where his active interest in many phases of agriculture had free sway.

Some who read these paragraphs will be old friends of Fred Albee, some will be men of a younger group who were stimulated by his demonstrations and clinics, many will be acquainted with him only through the written word. All will join in tribute to a man who did much for surgery and especially for orthopaedic surgery. His efforts of a lifetime aided, and brought relief from pain to many patients.

BENJAMIN FRANKLIN BUZBY

1891–1944

Dr. Benjamin Franklin Buzby of Philadelphia died on October 22, 1944, at the age of fifty-three years. He held the positions of orthopaedic surgeon to the Germantown Hospital in Philadelphia, the Cooper Hospital in Camden, New Jersey, the Burlington County Hospital in Mount Holly, New Jersey, and of consulting orthopaedic surgeon to the New Jersey State Hospital for Tuberculosis at Lakeland.

He was born July 31, 1891, at Swedesboro, the son of Dr. Benjamin F. and Emma Holbrook Buzby. He received his degrees of Bachelor of Arts and Doctor of Medicine from the University of Pennsylvania in 1911 and 1914, respectively.

During the last War he served overseas as a Captain in the Army Medical Corps. He was President of the Camden County Medical Society during 1937–1938.

He was a member of The American Orthopaedic Association, and of The American Academy of Orthopaedic Surgeons, a Fellow of the American College of Surgeons and of the Philadelphia Academy of Surgery.

Dr. Buzby contributed many papers to orthopaedic literature, the one on the functional results of excision of the elbow being particularly noteworthy. He was a very hard worker with almost unlimited energy and enthusiasm. He was of very honest and upright character, was devoid of all petty meanness, and was respected and admired by his associates.

He was a member of the Philadelphia Racquet Club, the Philadelphia Country Club, the Camden City Club, and the Pine Valley Golf Club.

He is survived by his wife, Mabel, and by two children, a son, aged seventeen, and a daughter, aged nineteen, to all of whom he was particularly devoted.

News Notes

THE BRITISH ORTHOPAEDIC ASSOCIATION

The Annual Meeting of The British Orthopaedic Association was held in London, on December 15 and 16, 1944, under the presidency of Mr. St. J. D. Buxton. The principal subjects of discussion the first day were the vascularization of muscles, the denervation and re-innervation of voluntary muscles, and certain phases of war surgery.

In discussing vascularization of muscles, Professor W. E. Le Gros Clark said it is well known that most muscles are supplied by two or more main blood vessels, and injected specimens show clearly that their branches effect a number of anastomotic connections inside the muscle. But such material gives no real indication of the adequacy of these connections for the establishment of a collateral circulation; nor does it show whether interruption of one of the main vessels, or of one of their intramuscular branches, may lead to a localized ischaemia severe enough to be of practical importance. These problems have been studied in rabbits by the ligature of blood vessels supplying muscles, the results being assessed partly by subsequent histological examination, and partly by using a highly diffusible dye, bromophenol blue. This dye rapidly colors all normal muscles after intravenous injection, and is of particular value for assessing the physiological efficiency of the circulation, since it indicates the degree of interchange between the capillaries and muscle tissue, even when a feeble circulation in the main blood vessels may be still present. The efficiency of the anastomotic connections was found to vary considerably in different muscles. In some, such as the tibialis anterior, ligature of one of the vessels of supply leads to a sharply defined area of ischaemia. Two days after ligature of the lower vessel of supply to the tibialis anterior, intravenous injection of bromophenol blue stains the upper half of the muscle to a normal intensity, but the lower half remains almost entirely unstained, and the boundary between the two areas is sharply defined. The normal vascularization of the lower half of the muscle is not restored for about a week. If both of the main vessels supplying the tibialis anterior are ligatured, revascularization is delayed for two weeks. In experiments in which small steel ball bearings were shot through the adductor muscles of rabbits, at velocities of 250 to 1000 meters per second, localized and sharply defined areas of ischaemia were produced, as a result of interruption of the muscle vessels. Histological study of the unstained areas of muscle in these experiments showed that most of the muscle tissue had undergone necrosis. The necrotic tissue is removed quickly by the invasion of granulation tissue with abundant macrophages, and its removal is soon followed by the regeneration of new muscle fibers. The experiments show that in the muscles of the rabbit there is a remarkable potentiality for regeneration in devascularized tissue, and that, in spite of anastomotic connections, the interruption of one vessel of supply to a muscle, or of one of its branches, may lead to a relatively extensive and well defined area of ischaemia, lasting for several days. This is important in relation to the infection of muscles in war wounds.

Dr. Ruth Bowden demonstrated the importance of maintaining function in voluntary muscles, denervated as a result of peripheral-nerve injury. In such cases, atrophy is most rapid in the early stages of paralysis, when there is an increase of connective tissue, associated with wallerian degeneration in nerve fibers, and obliteration of the terminal Schwann tubes and motor end plates. Eventually, as muscle fibers continue to atrophy, they are replaced by fat and by connective tissue. Finally, the muscle may resemble tendon. Up to a year after denervation, a fair degree of functional recovery may be expected; nevertheless, the atrophy and replacement by connective tissue starts after three months. The reversibility of the changes in muscle depends upon such things as sepsis, age, mobility of the limb, and physiotherapy, as well as upon the nature of the lesion in the nerve itself. The electrical changes in denervated muscle are due, not so much to degeneration, as to atrophy. The more sluggish response to galvanic stimuli is due to the impulse being conducted through muscle, instead of through nerve. The response may disappear altogether, if atrophy is advanced. Electromyography reveals changes accompanying fibrillation, which persists as long as any denervated contractile fibers remain, and the special type of action potential noticed during the early stages of re-innervation. Dr. Bowden stressed the value of galvanism in maintaining muscle activity, and in limiting the degree of atrophy. It must be regular, and be started as soon as possible after injury. Contractures which may develop in denervated muscle, because of the connective-tissue formation, can be retarded by physiotherapy, and may be prevented by daily movements throughout the whole range of the joints of the limb. Splinting of paralyzed muscles should never maintain complete immobility.

Lieutenant Colonel E. A. MacNaughton, Royal Canadian Army Medical Corps, described the technique of early wound closure and treatment in plaster of ten compound fractures of the femur. Provided that the immediate primary treatment had been adequate,—excision of the wounds, and general treatment with blood transfusions, penicillin, or sulfonamides—the thigh wounds in these compound fractures were

completely closed, without drainage, a week or so later. Closure was accompanied by accurate reduction of the fracture, and, where required, stainless-steel wires or vitallium screws were used in its fixation, without interfering with wound healing. Colonel MacNaughton emphasized the importance of adequate preparation of the patients for operation by rest, replacement of blood loss, further penicillin before and after operation, and avoidance of examination of wounds in the wards before operation.

Lieutenant Colonel R. Zollinger, Medical Corps, Army of the United States, questioned the value of sulfonamide drugs inserted into wounds. This is unnecessary if the primary excision has been adequate. Sulfonamides thus inserted do not penetrate far into crevices, where it is often important to maintain a high concentration of the drugs; this could be ensured only by adequate general administration.

On the second day there was a discussion on amputations and limb-fitting at Queen Mary's Hospital, Roehampton.

Mr. F. G. St. Clair Strange read a paper on the "Amputation Stump, in Health and Disease". The amputation stump must be considered a new and normal organ, on the perfection of which will depend the health and happiness of the patient. It should be an evenly truncated cone, having the smoothness of skin and scar mobility which follows healing by first intention, and with no scarring or oedema in the subcutaneous tissues. The stump requires an internal scar, between the cut surfaces and the top surfaces of the flap; normal structure and function of the muscles inserting into the stump; rounding off of the bone end, with its covering layer of compact bone; and the special adaptation of function in the stump to control the artificial limb. The flaps should be rounded, and should contain deep fascia, in order to retain lymphatic, blood, and nerve supply to the skin. There must be minimal trauma of nerves. Bone and periosteum must be cut at the same level; and hemostasis and skin suture must be carefully done. Postoperative care should avoid the development of flexion contractures. Mr. Strange stressed the importance of minimal disturbance of dressings. Elastic bandaging of the stump should be used from the twelfth day, to shrink the stump without forming a "waist"; non-resisted exercises should be encouraged from the twelfth day, whereas progressive resisted exercises do not begin until three and a half weeks after amputation. Stumps are ready for measuring in four to six weeks, and are ready for the artificial limb by the time it is made.

Professor N. Priorov gave a résumé of the experiences with amputations in a large area under his control in Russia. Plaster was applied to the stumps to facilitate transit in cases of primary guillotine amputations in field hospitals. The first dressing was never done before the eighth day. Secondary suture of long skin flaps was often done with sutures inserted through plastic buttons, which can be pulled up gradually until closure is effected. The operative technique included muscle tamponade of the end of the bone canal. Temporary bucket peg-leg prostheses are extensively used.

Mr. George Perkins emphasized the importance of the deep fascia and its treatment in providing a mobile scar.

Colonel Stout, New Zealand Army Medical Corps, said that, in the New Zealand Army, all amputations were left open until the fourth or fifth day, and were then sutured; they were expected to heal by first intention.

Major Mather Cleveland, Medical Corps, Army of the United States, said that American Army surgeons were told to carry out circular amputations at the lowest possible level. In most cases, these were followed by skin traction within a plaster bucket. The soldier was then evacuated to the interior, where definitive treatment was carried out.

Professor T. P. McMurray asked surgeons not to be hasty in carrying out amputations; even a bad limb of his own might be more acceptable to a man than an artificial one.

Dr. A. J. Craft demonstrated all the standard limbs supplied by the Ministry of Pensions.

Mr. R. D. Langdale Kelham, in a paper on amputations in children, stressed the need for making stumps as long as possible, because the stumps of children do not grow as much as their normal limbs.

Colonel Rex Diveley, Medical Corps, Army of the United States, presented a moving picture film, dealing with the life of a man who had two arms amputated and yet attained a high degree of independence.

Major John Charnley, Royal Army Medical Corps, demonstrated an adjustable weight-bearing caliper splint, designed on the Thomas principle, but suitable for mass production in a variety of standard sizes, having a ring for ischial-bearing, which is adjustable within limits for different thigh circumferences, and upright irons adjustable for length by a screw-fitting extension. With a suitable supply of basic parts, fitting and supplying such an appliance took an hour or two, compared with the several weeks required for a product made to measure.

During the meeting honorary membership was conferred on Sir Alfred Webb-Johnson, President of the Royal College of Surgeons, and on Mr. J. Rhaiadr-Jones, Chairman of the Executive Committee of the Central Council for the Care of Cripples. Other new members elected were:

Full Members:

T. P. Kilner, F.R.C.S., London, W. 1.
A. H. McIndoe, F.R.C.S., London, W.1.
Rainsford Mowlem, F.R.C.S., London, W.1.

Associate Members:

Douglas Freebody, F.R.C.S.E., Putney, S.W.15.
W. Herschell, M.B., Ch.B., Stanmore, Middlesex.
Surg. Cdr. Claude Keating, R.N., Brisbane, Australia.
Flt. Lt. F. B. Kiernander, R.A.F., Oxford.
Surg. Lt. Cdr. R. A. Mogg, R.N.V.R., Cardiff, Wales.
Dr. W. W. Ollerhead, London, Ontario, Canada.
J. D. Raftery, F.R.C.S., New Barnet, Hertfordshire.
Squad. Ldr. W. T. Ross, R.A.F., London, W.2.
Christopher Rowlands, M.B., Ch.B., Llanrhaiadr, Oswestry.
Squad. Ldr. T. B. Russell, R.A.F., Thornton Hall, Lanarkshire.
S. Smith, M.B., Ch.B., Glasgow, Scotland.
Squad. Ldr. E. Somerville, R.A.F., Halton, Wendover, Buckinghamshire.
Flt. Lt. R. A. Trevethick, R.A.F., Sheffield, 11.
Surg. Lt. J. Wishart, R.N.V.R., Glasgow, N.W., Scotland.

In the January issue of *The Journal* was given a list of Fellows of **The American Academy of Orthopaedic Surgeons,** elected during the year 1944. The name of Martin Batts, Jr., should have been included. Dr. Batts was elected to Fellowship, but died on July 8, before he received his diploma which has been awarded posthumously.

The Fifty-Ninth Annual Meeting of **The American Orthopaedic Association,** planned for May 28 to 31, at The Homestead, Hot Springs, Virginia, has been cancelled at the request of the Office of Defense Transportation.

ACKNOWLEDGMENTS

The Journal wishes to acknowledge the receipt of the following publications sent to the Editorial Department:

Anais Paulistas de Medicina e Cirurgia (São Paulo, Brasil), XLVII, No. 6; XLVIII, Nos. 1, 2, e 5, 1944.
Analecta Medica (Mexico), V, Nos. 3 y 4, 1944.
Boletim do Sanatório São Lucas (São Paulo, Brasil), V, No. 12; VI, Nos. 1, 2, e 5, 1944.
Boletin del Colegio Médico de la Habana (Cuba), VII, Núms. 9, 10, y 12, 1944; VIII, Núm. 1, 1945.
Boletines de la Sociedad de Cirugía de Rosario (Argentina), XI, Nos. 3, 4, y 7, 1944.
Boletines y Trabajos de la Sociedad de Cirugía de Córdoba (Argentina), V, Nos. 4 y 5, 1944.
The Bulletin of the U. S. Army Medical Department (Carlisle Barracks, Pennsylvania), Nos. 81, 82, and 83, 1944; Nos. 84, 85, and 86, 1945.
The University of Chicago Announcements. The School of Medicine, Sessions of 1944–1945. XLIV, No. 13, 1944.
Child Development Abstracts and Bibliography (Washington, D. C.), XVIII, Nos. 3 and 4, 1944.
Cleveland Clinic Quarterly (Ohio), XI, No. 4, 1944; XII, No. 1, 1945.
Current Medicine (Los Angeles, California), XII, No. 1, 1945.
Harper Hospital Bulletin (Detroit, Michigan), II, No. 3, 1944.
The Johns Hopkins University Circular, School of Hygiene and Public Health, Catalogue Number, 1944–1945. Baltimore, The Johns Hopkins University, 1944.
Médica (Matanzas, Cuba), III, Núms. 4, 5, y 6, 1944.
National Foundation for Infantile Paralysis, Inc. (New York, N. Y.), Annual Report, 1944; Miracle of Hickory, Publication No. 53, 1944.
National Foundation News (New York, N. Y.), IV, No. 2, 1944; Nos. 4 and 5, 1945.
National Society for Crippled Children of the U. S. A., Inc., Annual Report, 1944.
El Nuevo Hospital (La Habana, Cuba), III, Núms. 1–10, 1944.
The Physiotherapy Review (Chicago, Illinois), XXIV, No. 6, 1944; XXV, No. 1, 1945.
Radiography and Clinical Photography (Rochester, New York), XX, No. 2, 1944.
Revista Cubana de Obstetricia y Ginecología (La Habana, Cuba), VII, Nos. 1 y 2, 1945.
Sanidad y Beneficencia Municipal (La Habana, Cuba), III, Núm. 4, 1944; IV, Núm. 1, 1944
War and Postwar Rehabilitation and Reconditioning, The Baruch Committee on Physical Medicine, 1944.

Current Literature

SHOULDER LESIONS. H. F. Moseley, M.A., D.M., M.Ch. (Oxon.), F.R.C.S. (Eng. and C.), F.A.C.S. Springfield, Illinois, Charles C. Thomas, 1945. $4.50.

The expressed purpose of this book is to make available to the reader a short up-to-date account of current knowledge pertaining to certain painful lesions of the shoulder. This purpose is carried out in an orderly and readable fashion so that the busy practitioner will encounter a minimum of difficulty in obtaining a comprehension of the basic pathology, differential diagnosis, and accepted forms of therapy for the various forms of painful shoulder so often encountered.

An introductory chapter deals with normal anatomy and physiology; and the relative importance and interdependence of the various units of the "arm trunk mechanism" are emphasized and illustrated by clinical examples. Following a description and discussion of the general points of clinical examination, the detailed points of examination, along with the basic pathology and various forms of therapy, are discussed in successive chapters dealing with cuff tears, subluxations and dislocations, calcific deposits, the bicipital syndromes, and periarthritis with its allied conditions. Dr. F. L. McNaughton contributes an excellent chapter, which in twenty-two pages covers the neurological aspects of shoulder pain in a comprehensive manner; and Dr. Jean Bouchard and Dr. C. B. Peirce a chapter of twenty-six pages covering x-ray examination and therapy. The commoner operations are described and supported by case reports. Proper emphasis is laid on re-education of function in a separate chapter, which in its detailed discussion of rehabilitation procedures will be of great value to the reader.

The only major adverse criticism possible is that the discussion of fractures is confined to less than four pages. The common bone injuries of the shoulder girdle would seem to be worthy of a more important place than has been allotted them.

The work is well illustrated and accompanied by an excellent bibliography. It will constitute a valuable manual of shoulder lesions for the general practitioner.

QUISTES SIMPLES DE LOS HUESOS (SIMPLE BONE CYSTS). Oscar R. Maróttoli. Buenos Aires, El Ateneo, 1943.

This is an excellent monograph on the subject of simple bone cysts. It comprises 220 pages, and includes about 240 figures, most of them preoperative and postoperative x-ray studies of the author's cases. It is well presented, written in simple, clear, and straightforward style, and is a thorough exposition of the subject. It can be read rapidly and with interest, and is so well organized that one can readily use it as a reference to obtain the outstanding opinions on experimental, pathological, and clinical aspects of simple bone cysts.

The chapters on pathogenesis and gross and microscopic pathology are especially good, and numerous illustrations accompany the text. The experimental studies made by the author are discussed, but not elaborated upon to the exclusion of the clinical side. The chapters on roentgenographic signs, and the differential diagnosis of bone cysts from dystrophy, inflammatory and metabolic lesions, and tumors are carefully presented.

With this material for a background, the operative and postoperative methods of treatment are discussed, and the results recorded with particular emphasis on the author's cases. An honest effort has been made to solve this therapeutic problem to the best of our present knowledge.

This is a valuable monograph.

THE 1944 YEAR BOOK OF INDUSTRIAL AND ORTHOPEDIC SURGERY. Charles F. Painter, M.D., Editor. Chicago, The Year Book Publishers, Incorporated, 1945. $3.00.

The reader of a year book wishes to be introduced to the most important contributions on the subject to the medical literature of the year. The actual value of such a book depends, therefore, upon the care and good judgment with which the articles reported have been selected.

The 1944 Year Book of Industrial and Orthopedic Surgery, as its predecessors, is a review of the best contributions to these fields during the past year. In the section on Orthopedic Surgery, certain subjects seem to have received special emphasis in the literature. For instance, there have been many valuable articles on lesions of the shoulder, and the better understanding of dislocated and herniated intervertebral discs has led many authors to write upon these conditions, their causes, and their place in differential diagnoses. Surgeons in the Armed Services have offered for publication reports of unusual cases and studies of the more common injuries of the locomotor system. Conditions seldom seen in private practice have been observed very frequently in Army personnel.

Part II is devoted to Industrial Medicine and Surgery, and the articles to which reference is made deal with the general problems of health in industry, as well as the unusual conditions and hazards of wartime, and the specific problems of occupational diseases.

This Year Book meets a real need, and is an excellent compilation of the important contributions in this field during the past year.

Modern Methods of Amputation. Edmundo Vasconcelos. (With an Introductory Survey of the Development of Amputations by Major General Norman T. Kirk, M.C., Surgeon General of the United States Army.) New York, The Philosophical Library of New York, Department of War Medicine, 1945. $10.00.

The text, which pertains to the timely subject of amputations, opens with an Introductory Survey on the Development of Amputation by Major General Norman T. Kirk, whose contributions to this subject are well known. This Survey is reprinted in its entirety from an article appearing in the *Bulletin of the Medical Library Association*, April 1944. It is written in an interesting and scholarly manner, indicative of extensive historical research, and is a valuable contribution to the history of amputations, particularly as related to war. There are several excellent illustrations of historical interest, which have been reproduced from ancient and mediaeval writings.

The first three chapters deal with general considerations, including indications for amputation, sites of election, and preoperative and postoperative treatment. These subjects are well covered by the author, who is Professor in the University of São Paulo. In the main, his ideas are in agreement with those widely accepted. The influence of surgical writings from continental Europe is apparent. Some of this latter material is not altogether in accord with practice in the United States and Great Britain.

Chapters IV and V contain detailed descriptions of the technique of individual amputations, and they are thorough and comprehensive. Considerable space is devoted to a description of complicated amputations through the tarsal bones, many of which are not accepted in this country. Where satisfactory prostheses are not readily available, such operations may be useful, but where the art of limb making is highly developed, amputations of this type are not recommended. Amputations at a higher level are more easily performed, and most surgeons consider them more satisfactory.

The greatest value of the book lies in its well-executed pen drawings, which illustrate with great clarity the various steps in operative technique. The text is not well arranged, and the translation is poor, revealing a surprising lack of familiarity with English medical terms. The result is awkward and rather stilted, and it is difficult to determine the author's exact meaning in many parts of the text.

Aids to Orthopaedic Surgery and Fractures. I. E. Zieve, M.A. (Capetown), F.R.C.S. (Eng.). Ed. 2. London, Baillière, Tindall and Cox; Baltimore, The Williams and Wilkins Company; 1944. $1.75.

This is a second edition of a small book of 260 odd pages. It is really a glorified dictionary of orthopaedic surgery, and covers practically everything in a superficial, but most intelligent way. It contains very little operative description of anything, except in general terms. There is no bibliography and there are no illustrations. The treatments, including the surgical treatments of all the various conditions described, are most conservative. Certain standardized and well-recognized methods of treatment and operation are advocated, rather than any discussion of operative procedures which might be employed for each type of case or condition. This, of course, leaves the uninitiated surgeon with but one choice.

As one reads it, in places, it seems a little bit old-fashioned, and some of the British terms are not in common usage in this country. On the whole, it is a very interesting and useful book, and certainly reduces things to first principles. The subject matter is very clearly presented in eight chapters and is well grouped,—fractures, congenital deformities, acquired deformities, and so forth. For the physician in general practice, and even for an orthopaedic surgeon, it is a very useful, small book to own.

A List of Books and Pamphlets on the History of Surgery and Orthopedic Surgery. In the Collection of Dr. H. Winnett Orr, Lincoln, Nebraska. Ed. 2. Lincoln, Jacob North & Co., 1945.

This is a catalogue of his own library, compiled by Dr. Orr. Included with the books, many of which are old and rare, are the twelve scrap books which Dr. Orr has built over the years. Five of these reveal the development of the Orr method of treatment of compound fractures and osteomyelitis; another, the experiences of the American Orthopaedic Unit in World War I; and others, memorabilia of The International Orthopaedic Society, The Nebraska Orthopaedic Hospital, and The American Orthopaedic Association. The remainder are devoted to the history of surgery and of orthopaedic surgery, to Lord Lister, and to Dr. Orr's own private and professional life.

Dr. Orr's books constitute one of the finest private surgical libraries in America. The mere list of titles is a delight to the bibliophile. To the student of the history of surgery and the development of the older and the modern orthopaedic surgery, this library is an important source.

PHYSICAL TREATMENT OF ANTERIOR POLIOMYELITIS. Diana B. Kidd, C.S.M.M.G. London, Faber and Faber Ltd., 1943. 6 shillings.

In the introduction to this book, Maude Forrester-Brown, a well-known Scottish orthopaedic surgeon, is quoted as saying that three qualifications are necessary for a physiotherapist when treating patients with anterior poliomyelitis: an accurate knowledge of anatomy, great patience, and a gift of arousing the patient's cooperation.

The author stresses these qualifications in the text. Treatment is divided into the acute, the convalescing, and the chronic stages, and specific treatment is described for each phase of the disease. Attention is paid to general health conditions, and to the maintenance of improved circulation by means of massage and joint movements. A system for recording improvement of muscles is included. The author cites the advantages of the suspension-sling type of re-educational therapy over pool therapy. However, children usually respond readily to underwater exercises and enjoy themselves thoroughly. It is a great uplift to youngsters, who have some physical handicap, to feel that they are able to excel in any type of physical effort.

The suspension-sling exercises, with additional pulley weights which provide graded resistance for specific muscle groups, are explained, and pictures demonstrating the framework and the positions of the joints to be re-educated accompany the text.

A discussion of the possibilities of electrical stimulation and occupational therapy completes this practical handy textbook, which is to be recommended to students, and those practising physiotherapy in anterior poliomyelitis conditions.

THE ART OF RESUSCITATION. Paluel J. Flagg, M.D. New York, Reinhold Publishing Corporation, 1944. $5.00.

In the preface, the author states that his purpose is "to tell the reader what to do when faced with an acutely asphyxiated patient about to die". The first three sections, covering the first quarter of the volume, define the problem from a physiological and medical standpoint, and discuss the indications and methods for treatment. The various causes of asphyxia, such as poisoning from gases, submersion, electrocution, and respiratory obstruction are next described at length, and particular instructions are given for dealing with the different situations. Dr. Flagg suggests the organization of the teaching and administration of gas therapy including anaesthesia as a specialty, to be referred to as "pneumatology."

This book contains a mass of valuable material. The sections on methods of resuscitation and on transportation of the unconscious patient are particularly useful. The verbose and overdramatic style detracts from so serious a book. In spite of this criticism, "The Art of Resuscitation" is undoubtedly a useful book.

TODESFALL AN FETT-KNOCHENMARKEMBOLIE UND URÄMIE NACH "INTRADURALER" PER-ABRODIL-MYELOGRAPHIE (A CASE OF DEATH FROM FAT EMBOLISM AND URAEMIA FOLLOWING INTRADURAL PERABRODIL MYELOGRAPHY). A. Karlén. *Acta Chirurgica Scandinavica*, LXXXVII, 497, 1942.

A case is reported in which epidural myelography with twenty cubic centimeters of 35 per cent. perabrodil terminated fatally. An attempt was made to inject the material through the sacral hiatus so that it remained epidural in the diagnosis of protruded intervertebral disc. In spite of great care the fluid was deposited intradurally. In three-quarters of an hour the patient began to have back pain and cramps. His back muscles became spastic and boardlike. He became blue and cyanotic with cold perspiration. Three hours after the injection, he became unconscious. Three days later, the patient died, apparently because of uraemia, complicated by a fat embolism from the severe convulsions.

The writer could find no report of a similar case of death from attempted perabrodil epidural myelography. He did find nineteen fatal cases after the use of the same drug in pyelograms. Perabrodil is 49.8 per cent. iodine.—*Walter P. Blount, M.D., Milwaukee, Wisconsin.*

OSTEOPLASTISCHE VERANKERUNG VON METALLPROTHESEN BEI PSEUDARTHROSE UND BEI ARTHROPLASTIK (OSTEOPLASTIC IMPLANTATION OF METAL PROSTHESES IN PSEUDO-ARTHROSIS AND IN ARTHROPLASTY). I. Boerema and J. de Waard. *Acta Chirurgica Scandinavica*, LXXXVII, 511. 1942.

Two cases in the human, and several in dogs are reported, in which stainless steel was implanted to bridge bone defects. In one case a fenestrated tube of bone was implanted in an ununited humerus. The function was good after one year.

In the second case a stainless-steel elbow joint was used to bridge a defect. One arm of the prosthesis was firmly driven into the humerus. The other was made fast to the ulna with some difficulty. At the end of fourteen months, there was 20 degrees of motion,—from 80 to 100 degrees.—*Walter P. Blount, M.D., Milwaukee, Wisconsin.*

Denna Festskrift Tillägnas Professorn I Ortopedi Vid Kungl. Karolinska Mediko-Kirurgiska Institutet, Henning Waldenström. (Memorial Volume.) *Acta Chirurgica Scandinavica*, LXXXVII, Numbers 2, 3, 4, 1942.

Numbers two, three, and four of Volume LXXXVII of the *Acta Chirurgica Scandinavica* appeared as a memorial book dedicated to Professor Henning Waldenström on his sixty-fifth anniversary, August 14, 1942. Twenty-eight students and friends contributed a variety of brief articles of orthopaedic interest. Stereoscopic photography, the erroneous diagnosis of sarcoma, the epidural injection of abrodil in the diagnosis of disc protrusion, urinary calculi in hyperparathyroidism, ossifying hematoma, bone grafting in the treatment of recurrent dislocation of the shoulder, and the etiology of coxa plana are some of the varied subjects.

Probably because of the War, the contributors were limited to the Scandinavian countries, and principally Sweden. Soon after the publication of this volume, Professor Waldenström retired as Professor of Orthopaedics at the Karolinska Institutet. His place was taken by Sten Friberg.—*Walter P. Blount, M.D., Milwaukee, Wisconsin.*

Der Einfluss Örtlicher Novocaininjektionen auf die Frakturheilung (The Influence of Local Novocaine Injection on Fracture Healing. An Experimental Study). Einar Bohm and Gosta Flyger. *Acta Chirurgica Scandinavica*, LXXXIX, 97, 1943.

There is a growing tendency to treat certain linear fractures by repeated novocaine injection without immobilization. There are numerous reports in the literature of cases where such treatment has produced more rapid healing with less disability. To investigate this method, the writers broke the right fibula just above the malleolus in a series of rats. The fractures were produced with little or no displacement. Two-tenths of a cubic centimeter of a sterile 1 per cent. novocaine solution was injected directly into the site of this fracture. For the first week the injection was carried out daily; during the second week, every second day; and during the third week, every third day. Roentgenograms were taken and the rats sacrificed at various stages of healing from the third to the twenty-fifth day.

On the basis of their studies, the authors conclude that:

1. Hyperaemia sets in sooner in the case of the animals treated with novocaine than in those not treated. Maximum hyperaemia was reached in ten days in the treated animals, but not for twenty-five days in the untreated. After twenty-five days in the treated fractures, the vascular condition about the fracture had returned to normal.

2. Healing appeared to proceed more rapidly following injection of novocaine. After twenty-five days in the treated cases, complete reorganization of the callus occurred. After twenty-five days the control cases still had spongy callus which even contained connective tissue. Only one of seven of these cases exhibited any reorganization. Convincing illustrative sections at six, ten, fourteen, and twenty-five days are submitted.—*Walter P. Blount, M.D., Milwaukee, Wisconsin.*

Synovial Sarcoma. Cushman D. Haagensen and Arthur Purdy Stout. *Annals of Surgery*, CXX, 826, 1944.

Synovial Sarcoma and Normal Synovial Tissue Cultivated *in Vitro*. M. R. Murray, Arthur Purdy Stout, and I. A. Pogogeff. *Annals of Surgery*, CXX, 843, 1944.

These articles are combined for review because the laboratory studies were undertaken to obtain confirmation of the mesothelial nature of synovial sarcoma by tissue culture in three cases. An investigation of the subject seemed necessary because many reports on this rare form of tumor were disappointing, since a considerable number of the cases were, in reality, xanthomatous giant-cell tumors, tumor-like hyperplasias of synovial tissue, or other benign lesions curable by excision.

The tissue from three cases of human synovial sarcoma was cultivated *in vitro* and was compared with similarly treated normal synovial tissue from the knee joint of the adult rat. The normal synovial cell appears to be a specific type of cell distinct from other epithelium and from the fibroblast. But the synovial sarcoma appears to be a distinct type of neoplasm exhibiting certain similarities to the mesothelioma.

The three tumors had definite histological characteristics. They were composed of an inextricable admixture of mesothelial cells, with strands of active hyperchromatic cells resembling fibrosarcoma, associated with reticulin fibers. It was decided to regard these as the characteristic features of such tumors. On this basis, the previously reported cases were re-examined, and those which failed to satisfy the criteria were rejected. This screening yielded ninety-five cases; to these were added nine new cases which are reported in detail.

The synovial sarcoma is a highly specialized and rare form of neoplasm which attacks the extremities. It develops slowly, is more common in young adult males, and metastasizes through the blood stream or occasionally to the regional lymph nodes. The diagnosis should be established by histological examination of material obtained through a small non-traumatizing incision. Treatment is by high amputation and perhaps regional lymph node dissection. Roentgenotherapy is ineffective.

Of the entire group of 104 cases studied by the authors, only three are known to be free of metastases more than five years after treatment.—*Paul P. Swett, M.D., Bloomfield, Connecticut.*

War Surgery in Africa. W. H. Ogilvie. *The British Journal of Surgery*, XXXI, 313, 1944.

The lot of the wounded man in this war is better than that of his father. His suffering has been minimized and his chances of useful survival are greater. The soldier of today is a more physically-fit man, and he fights under better conditions. The chances of relief of hemorrhage and shock by blood and plasma are better and the sulfonamides have reduced the dangers from infection. Methods of immobilization are better and so are the methods of transport.

It is impossible to reduce the surgery of modern warfare to a system. Each military enterprise is a fresh surgical problem. Local factors—such as the time-lag in reception, the equipment of the unit, and the conditions of evacuation—will modify any set of general principles which are laid down.

First-class surgery can be done under very simple conditions, provided the wounded man can be placed in the care of competent surgeons without delay.—*Ernest M. Daland, M.D., Boston, Massachusetts.*

Studies in the Pathology of Human "Immersion Foot". W. Blackwood. *The British Journal of Surgery*, XXXI, 329, 1944.

Pathological material from fourteen cases of immersion foot has been studied. The article is illustrated by many photographs (some in color) and photomicrographs.

"A histological study of tissues from cases of immersion foot showed that damage was done to all tissues in the extremity. Blood vessels, muscles, nerve trunks, and bone were particularly examined. The relative severity of injury to the tissues varied, being most severe in nerves and muscles. Material from early survivors was not available, but it is likely that the early histological reactions are similar to those seen in the experimental animal. There was evidence of restoration towards or to normal of tissues which had not been killed by the initial trauma. Nerve regeneration occurred and, though slow, did not appear to be grossly so; and denervated muscle returned to normal, provided that the delay was not so long that irreversible degeneration and fibrosis had ensued."—*Ernest M. Daland, M.D., Boston, Massachusetts.*

Observations on the Regeneration of the Semilunar Cartilages in Man. I. S. Smillie. *The British Journal of Surgery*, XXXI, 398, 1944.

Fourteen patients were submitted to a secondary operation after all or part of the semilunar cartilage had been removed. It was found that where the whole cartilage had been removed a new one of about the same shape and appearance had formed, but it was composed entirely of fibrous tissue. Replacement also occurred after partial removal of the meniscus, but the attachment of the new tissue to the old was a weak one, and the replacement was probably not as good as a total replacement.

In five cases, injury was found in the replaced cartilage, but in every case it was found that there had also been previous injury to the cruciate or collateral ligaments, with a resulting unstable knee joint subjecting the new meniscus to undue strain.—*Ernest M. Daland, M.D., Boston, Massachusetts.*

El Procedimiento de Quesada en el Tratamiento de las fracturas diafisarias, irreductibles por tratamientos incruentos (Quesada's Method of Treatment of Diaphyseal Fractures, Irreducible by Closed Methods). Salvador de Lara. *Cirugía y Cirujanos*, XII, 179, 1944.

A description of the apparatus of Prof. Quesada is given by de Lara. This apparatus is used for the treatment of irreducible fractures of the shafts of the long bones. It consists of a plaster cast with an open metal frame over the area of the fracture. The usual methods of manipulation under anaesthesia and of traction are employed. If these are unsuccessful, open reduction is carried out through the open part of the Quesada apparatus. No internal fixation of the bones is used. The periosteum is carefully sutured. De Lara is opposed to the use of internal metallic fixation, because he believes that it produces trophic changes, delays healing, interferes with local circulation, and sometimes causes infection. The method of Quesada disturbs the physiology of the healing bone very little. Secondary displacements of the fragments are rarely seen with this method. The indications for this procedure are given as follows:

1. When it is not possible to obtain bloodless reduction manually;
2. When reduction cannot be maintained, because of deficient contact of the fragments;
3. When the fragments show jagged edges or teeth which prevent proper contact in the transverse plane;
4. When there is interposition of the soft parts;
5. When bone-grafting seems necessary;
6. In compound fractures.

The technique consists of immobilization in the Quesada apparatus for six to twelve days. Reduction is then carried out through the window of the apparatus. The periosteum is sutured and the soft parts are repaired. Traction is applied, when necessary to prevent bowing. Surgical intervention is thus carried out after any hemorrhage has been absorbed. Occasionally catgut or kangaroo tendon is required in oblique fractures. Sometimes in transverse fractures, one or two teeth are made in the ends to maintain reduction. The plaster is usually removed about nine days after the operation, and the limb is put in a protective plaster until the fracture is solid.—*John G. Kuhns, M.D., Boston, Massachusetts.*

El Método Fenestrado para el Enclavijamiento de las Fracturas del Cuello del Fémur (The Fenestration Method of Nailing Fractures of the Femoral Neck). Eduardo Alcívar Elizalde. *El Dia Médico*, XVI, 554, 1944.

Fractures of the femoral neck may be divided into three classes:

1. Cervicotrochanteric,
2. Transcervical,
3. Subcapital.

The method of Whitman gives excellent results in the treatment of fractures of the first group. It has markedly improved the results in the other classes by reducing the number of pseudarthroses. To minimize this tendency toward pseudarthrosis Lambotte suggested, and Delbet subsequently modified, the method of holding the cervical fragments together with a screw. Subsequently Smith-Petersen recommended the use of the flanged nail, instead of the screw. It is this method which the author employs.

However, he notes that nailing, whether by the open method or the closed, necessitates trained personnel and specialized equipment which is not always available. To offset this difficulty, the author recommends a combination method which he calls the fenestration method.

The first part of the procedure consists in reduction of the fracture and immobilization in a Whitman plaster. A roentgenogram is then made. If the reduction is deemed satisfactory, a window thirty by fifteen centimeters is cut in the cast, and a Smith-Petersen nail is inserted over a Kirschner-wire guide. At the end of two weeks, the cast is shortened, so as to permit greater motion in bed. A month and a half after operation, the long plaster is removed, a short spica is applied, and the patient is permitted to walk about with the aid of crutches. At the end of three months, the patient walks without plaster, but with the aid of a cane. At the end of five months, the nail may be removed, if the roentgenogram shows bony trabeculation across the site of fracture.—*Henry Milch, M.D., New York, N. Y.*

Compression of Seventh Cervical Nerve Root by Herniation of an Intervertebral Disk. Paul C. Bucy and Harvey Chenault. *The Journal of the American Medical Association*, CXXVI, 26, 1944.

The authors have reviewed the literature on herniated intervertebral discs. They report in detail a case with paraesthesia in the thumb, index and middle fingers of the right hand, which extended up the radial aspect of the forearm; with mild weakness in the right triceps but without difference in the triceps reflex; without motor weakness in the right hand, but with hypalgesia, hypaesthesia, and hypothermesia over the right thumb and index and middle fingers, and on the radial border of the forearm. A diagnosis of herniated disc between the sixth and seventh cervical vertebrae compressing the right seventh cervical nerve root was made, and was confirmed at operation. Removal of the herniated portion resulted in relief of the symptoms. —*Joseph H. Reno, M.D., Dallas, Texas.*

Fracture of the Base of the Thumb. A New Method of Fixation. Eric C. Johnson. *The Journal of the American Medical Association*, CXXVI, 27, 1944.

The author reports two cases of Bennett's fracture of the base of the first metacarpal, in which fixation of the fragments was carried out, after manual reduction, by Kirschner wires and a plaster cast. The wires were passed through the thumb and second metacarpal after reduction by traction; a cast was then applied. Such immobilization for six to eight weeks yielded an excellent result in each case. — *Brandon Carrell, M.D., Dallas, Texas.*

Hemorrhagic Complications, with Death Probably from Salicylate Therapy. C. T. Ashworth and J. F. McKemie. *The Journal of the American Medical Association*, CXXVI, 806, 1944.

Two case reports of patients receiving salicylate therapy are presented,—one, a woman, twenty years of age, who received 150 grains of sodium salicylate daily for seven days; the other, a boy, four months old, who received fifteen grains of acetylsalicylic acid in two days. In both cases, hyperpnea, hyperpyrexia, and convulsions preceded coma, followed by death. The outstanding findings at autopsy were: hemorrhagic changes, widespread over the whole body but particularly involving the brain, and severe widespread hyperaemia. The explanation of these findings is probably a combination of capillary damage and hypoprothrombinaemia produced by the salicylates. The literature upon such effects by salicylates is reviewed. Vitamin K is urged as supplemental therapy when large doses of salicylates are used.—*J. H. Reno, M.D., Dallas, Texas.*

The Effect of Penicillin on Rheumatoid Arthritis. Edward W. Boland, Nathan E. Headley, and Philip S. Hench. *The Journal of the American Medical Association*, CXXVI, 820, 1944.

Large doses of penicillin were given to ten soldiers, with proved early and progressive rheumatoid arthritis, who did not have irreversible changes (destruction of cartilage and subchondral bone, or notable flexion deformities). The dosage of penicillin, given intramuscularly, was from 120,000 to 320,000 units daily for

from fourteen to twenty days. There was no definite improvement as measured by laboratory tests. There was no significant improvement in the sedimentation rates or in the comparative leukocyte counts on synovial fluid, made before and after treatment. In seven of the ten cases, there was no significant subjective or objective improvement. One patient felt worse, but objectively was unchanged. Another felt better, but there was no definite objective improvement. The remaining patient had moderate subjective and objective improvement in some of the affected joints; the sedimentation rate increased slightly during treatment; but he was neither cured nor decidedly improved. The authors decided that their results offered no support to the idea that hemolytic streptococci are etiologically related to the disease; that it is not caused by any of the bacteria which are already known to be rapidly affected by penicillin; and that penicillin trials in treatment of rheumatoid arthritis should be deferred until the drug becomes much more plentiful.—*H. H. Beckering, M.D., Dallas, Texas.*

COMPRESSION FRACTURE RESULTING FROM ACCIDENTAL STIMULATION OF CAROTID SINUS. Charles U. Hauser. *The Journal of the American Medical Association,* CXXVI, 1029, 1944.

During the application of a forearm cast, while seated upon a stool, a patient fainted and his head slumped forward against his moderately tight neck band. A strong convulsion immediately gripped him, causing his back to flex sharply with all his flexors tightening in a tetanic spasm for a few seconds. He was then laid upon an examining table where he remained unconscious for the next five minutes. Subsequent roentgenograms of the spine revealed compression fractures of the eleventh and twelfth thoracic vertebrae, resulting in about 25 per cent. reduction in the width of the anterior portion of the bodies.

Several factors contributed to the convulsion. The right carotid sinus was found to be hyperirritable. The normal, fasting blood sugar level was 93 milligrams. Fatigue from several sleepless nights, apprehension over a flexion strain of the wrist, pain in the wrist, and the usual hospital aroma, added to the low glucose level, helped to lower the threshold for stimulation of the normally hypersensitive carotid sinus.

Although convulsions from stimulation of a hyperirritable carotid sinus are rare, this case serves to point out the importance of treating a patient in a horizontal position. This should interest those surgeons who may use compression of the neck in various diagnostic manoeuvres.—*D. K. Barnes, M.D., Dallas, Texas.*

GROWTH ARRESTS FOR EQUALIZING LEG LENGTHS. J. Warren White and Sam G. Stubbins, Jr. *The Journal of the American Medical Association,* CXXVI, 1146, 1944.

The authors present this paper to popularize a simple surgical procedure which they have found to be of great value in solving the problem when in children one leg is enough shorter than the other to produce immediate or probable future disability. The White method of epiphyseodiaphyseal fusion is presented in detail, and those interested in a review of this should consult the original article. The differences from the better known Phemister method are pointed out. This is, in effect, a ten-year report of the White method. A useful method of graphically recording the discrepancy in the length of the lower extremities is presented which is very feasible, and this article should be studied for the details. Growth in the lower extremities of boys is stated to cease at seventeen years of age and in girls one year earlier. White feels that growth arrest of the distal femoral epiphysis would retard the growth of that extremity at the rate of three-eighths of an inch per year; at the proximal end of the tibia and fibula the rate of retardation is a quarter of an inch. These figures for calculations have not been faulty in ten years' experience with 149 cases.

The operation should be performed largely on those children in whom, at the age of ten or twelve, there exists upward of two inches of shortening.

In the discussion of this paper, Dr. Hatcher points out that girls do not mature as regularly as boys do, and that they mature earlier. In general, epiphyseal arrests have no value in the female if menstruation has started, because after that time the girl will grow no more from the lower extremities; she will increase slightly in height from growth of the spine.—*J. H. Reno, M.D., Dallas, Texas.*

NERVE LIGATURE FOR PREVENTION OF AMPUTATION NEUROMA. M. A. Egorov. *Khirurgiya,* No. 4, 38, 1944.

The prevention of neuromata in amputation stumps is still a problem. The known methods are not entirely satisfactory. The author had occasion to observe satisfactory results obtained by one of his former assistants, who used a massive ligature applied to the neurovascular stump. Following this method, the author ligated the nerves in the amputation stumps of twenty-seven children. He also cites a similar procedure in three amputations on adults. He emphasizes the comparative absence of phantom pain in the immediate postoperative period. Experimental ligations of the nerves were performed on fourteen dogs, and postoperative neuromata did not develop.

The author recommends the use of silk ligatures, applied tightly and separately to each severed nerve.—*E. Kaplan, M.D., New York, N. Y.*

GUNSHOT WOUNDS OF THE JOINTS. *Khirurgiya,* No. 1, pages 2–82, 1944.

This is a general review of the entire subject. The issue is of special interest because it contains thirteen articles on gunshot wounds of the joints, and their management at the forward battlefront area, in base hos-

pitals, and in the rear. It encompasses experience from a large number of cases. The predominating opinion of most of the authors is that gunshot wounds of joints, especially of the hip joint, require early radical operations, including resections and even disarticulations.

The following is a list of articles in the issue:

On Gunshot Wounds of Articulations and Their Treatment	V. S. Levit
Pathological Anatomy of Gunshot Wounds of the Knee Joint	P. P. Dvijkos
The Treatment of Gunshot Wounds of Large Joints	E. K. Molodaya
On Joint Resections Following Gunshot Wounds, Based on Cases from Evacuation Hospitals of the Deep Rear	A. T. Lidsky
Gunshot Wounds of the Elbow Joint	A. I. Makhotina
On the Problem of Gunshot Coxitis	M. O. Fridland
Gunshot Wounds of the Hip Joint	T. S. Zatsepin
Hip Disarticulation in Gunshot Wounds of the Lower Extremity	N. I. Makhov
Gunshot Wounds of the Hip Joint and Their Treatment	V. A. Chernavsky
On the Problem of Gunshot Wounds of the Knee Joint	V. R. Braitsev
On the Problem of the Treatment of Gunshot Wounds of the Knee Joint in a Front-Line Evacuation Hospital	F. F. David
Gunshot Wounds of the Knee Joint Complicated with Pyarthrosis	I. S. Vengerovsky
Gunshot Wounds of the Foot and Ankle Joint	B. V. Ognev

E. Kaplan, M.D., New York, N. Y.

THE PARATHYROID GLANDS AND PARATHORMONE. Alfred Pope and Joseph C. Aub. *The New England Journal of Medicine*, CCXXX, 698, 1944.

This is a comprehensive review of what is known about the parathyroid glands and parathormone, and it is accompanied by an extensive list of references. The article is too extensive for abstracting, but it should be studied and filed for further reference. The authors conclude that "the treatment of hypoparathyroidism has been rendered simple and effective and the surgical management of hyperparathyroidism placed on a sound basis".—*Paul P. Swett, M.D., Bloomfield, Connecticut.*

A TOXIC FACTOR IN EXPERIMENTAL TRAUMATIC SHOCK. Joseph C. Aub. *The New England Journal of Medicine*, CCXXXI, 71, 1944.

The study of traumatic shock in World War I indicated that the cause of the syndrome was an unisolated toxin. Efforts to isolate this toxin were unsuccessful, and a reaction against the theory marked the period between the two wars. This was furthered by Blalock's and Phemister's convincing studies which showed the rôle of fluid loss in shock.

Because of the difference in appearance of both man and animals following bleeding and trauma, something other than plasma loss seems to be involved. In an effort to find this elusive factor, oedematous fluids from anoxic muscles were collected from experimental animals, and it was found that, in spite of rigid asepsis, such fluids were infected. Organisms of the gas-gangrene group were found in thirteen out of nineteen instances. The higher the number of the organisms, the more toxic or shock-producing were the effects when the fluid was injected into animals. This toxic factor seemed to be something other than the organisms, because the supernatant fluid was equally toxic, while the injections of the organisms alone resulted only in fever. Considerable interest centers in the question as to whether clostridia are commonly present in muscles, or whether they are introduced at the time of the injury. In eighteen elective orthopaedic operations clostridia were not found, but it has been shown that more than 30 per cent. of war wounds are contaminated by clostridia. The characteristic slow onset of shock in the war wounded agrees with the length of time required for the growth of bacteria and the formation of their toxins.

These experiments show the great importance of plasma loss in shock, and they also show the importance of infection as a toxic factor. Fortunately, methods are now available for alleviating both plasma loss and infection.—*Paul P. Swett, M.D., Bloomfield, Connecticut.*

PAIN AND DISABILITY OF SHOULDER AND ARM DUE TO HERNIATION OF THE NUCLEUS PULPOSUS OF CERVICAL INTERVERTEBRAL DISKS. Jost J. Michelsen and William J. Mixter. *The New England Journal of Medicine*, CCXXXI, 279, 1944.

Cord compression was formerly considered a diagnostic criterion in herniation of the cervical discs; it now seems likely that this feature was overemphasized. Root symptoms may just as well occur here as in the lumbar area. Michelsen and Mixter found cord compression in six cases, while nerve-root involvement occurred in eight cases.

Eight cases which were operated upon, are reported in detail. It is indicated that pain and disability of the shoulder and arm were prominent symptoms. There were lesions at the fifth interspace in four cases, at the sixth in three, and at the seventh in one. The clinical data were brought together in a syndrome that comprised root pain and local sensory and motor disturbances, as well as positive roentgenographic and

cerebrospinal-fluid findings. The distribution of the sensory abnormalities was compared with standard dermatome charts. Emphasis is given to the importance of a systematic neurological examination in cases of pain and disability of the shoulder and arm. The removal of the disc fragments by laminectomy or subtotal hemilaminectomy gave good results. The addition of this new entity to the long list of disorders which give rise to arm and shoulder signs and symptoms ought to be a great help in the clarification of these perplexing problems.—*Paul P. Swett, M.D., Bloomfield, Connecticut.*

USE OF SKELETAL TRACTION IN THE HAND. Milton C. Cobey, Harvey C. Hansen, and Marion H. Morris. *Southern Medical Journal,* XXXVII, 309, 1944.

Skeletal traction is often more efficient than skin traction, and it is more comfortable. Considerably more pull can be obtained, and reduction is more accurate. A simple and convenient type of skeletal traction is the ordinary surgical towel clip. Routine aseptic surgical technique is followed, with draping of the parts. A small skin incision is made, and the traction device is placed in the proximal end of the incision to prevent skin tension. Sterile dressings are used about the clip, and are not to be disturbed until the fracture has united. Some type of fixation, corks or adhesive, may be employed to prevent to-and-fro excursions of the clip. Pull is exerted in the longitudinal axis of the bone. The clip is inserted under local or general anaesthesia, the fracture is reduced, and traction is applied. This device is useful in fracture or dislocation of the thumb and of the metacarpals. After the clip has been inserted and dressed, a plaster cast with a banjo splint for traction is applied. The clip is not used for fractures of the phalanges. The use of skeletal traction in fifty-nine cases is reported.—*Fred G. Hodgson, M.D., Atlanta, Georgia.*

CLINICAL ANALYSIS OF 1,000 CONSECUTIVE CASES OF LOW BACK PAIN. WITH PARTICULAR REFERENCE TO SCIATIC PAIN CAUSED BY EXTRUSION OF THE INTERVERTEBRAL DISC. Franklin Jelsma. *Southern Medical Journal,* XXXVII, 372, 1944.

It was found that 484 of 1,000 cases of low-back pain presented sufficient clinical findings to warrant a diagnosis of a probable herniated disc. Forty-seven other focal lesions were found,—such as, slight compression fracture of the bodies of the vertebrae, metastatic tumors, spina bifida occulta, spondylolisthesis, and sacralization of the fifth lumbar vertebra. In many cases, hypertrophic arthritic changes were found. Palliative measures were used in all cases so long as the patient improved. Operation was done in 150 cases. Only 26 per cent. of the patients did not give a history of injury. Ten patients had more than one disc injury. In 70 per cent., the lesions were located at the fifth lumbar vertebra, and in 25 per cent., at the fourth lumbar. In 6 per cent., no disc lesion was found. Results were good in 90 per cent., fair in 4.5 per cent., and unimproved in 1.5 per cent. (two cases). There were no deaths. The question of fusion was not discussed.—*Fred G. Hodgson, M.D., Atlanta, Georgia.*

LANTZOUNIS PERIOSTEO-CAPSULOPLASTY FOR CONGENITAL DORSAL SUBLUXATION OR CONGENITAL OVERLAP OF FIFTH TOE. Byron B. King. *Southern Medical Journal,* XXXVII, 614, 1944.

A simple operation is described to reduce and to maintain an overlapped or dorsally subluxated fifth toe. A dorsal incision is made over the metatarsophalangeal joint. The extensor digitorum longus tendon to the fifth toe is divided as far distally as possible. The periosteum and the capsule are stripped from the dorsal, medial, and lateral surfaces of the joint. A hole is bored just behind the head of the metatarsal; the extensor tendon is run through this, and is then sutured to itself under enough tension to raise the metatarsal head. The periosteum and capsule are folded under the joint and are fastened by a single figure-of-eight suture, which makes these tissues act as a bow-string ligament to hold the toe down in normal alignment. The wound is closed, and an adhesive plaster dressing is all that is needed to hold the toe in place.—*Fred G. Hodgson, M.D., Atlanta, Georgia.*

SURGICAL TREATMENT OF OSTEOMYELITIS OF THE EPIPHYSIS OF THE HUMERUS AFTER GUNSHOT FRACTURES. G. Kh. Sarkisov. *Sovetskaia Medicina,* VI, 17, 1944.

Gunshot injuries of the shoulder joint with destruction of the head of the humerus require a resection of the head before the possible development of osteomyelitis and pyarthrosis. Complete hemostasis must be obtained and the wound packed without complete closure. Only approximation of the wound edges is necessary. Closed plaster-of-Paris casts should be avoided. If there is a profuse discharge, the wound should be irrigated and sulfonamide therapy applied. Physiotherapy should be started only after complete closure of the wound. Resection of the shoulder joint may restore the shoulder to good use, and even permit the patient's return to limited combatant duty.—*E. Kaplan, M.D., New York, N. Y.*

THE EFFECT OF SEX HORMONES ON SKELETAL METASTASES FROM BREAST CANCER. J. H. Farrow. *Surgery,* XVI, 141, 1944.

Farrow has reviewed the findings upon which the use of sex hormones in the treatment of skeletal metastases has been based. Statistical evidence of the benefit of castration in the treatment of skeletal metastases has not been too encouraging. Approximately one-third of the patients in the premenopause period

were benefited by this procedure. Approximately one-half of the patients treated by means of testosterone showed evidence of clinical and roentgenographic improvement. On the other hand, the administration of large doses of the synthetic androgens tended to increase rather than inhibit the activity of skeletal metastases.

The author reported treatment of a case of carcinoma of the breast, in which there were widespread skeletal metastases, by means of bilateral orchidectomy. There was almost immediate relief of symptoms, and regression of both local and osseous metastases. Farrow hazards the opinion that this improvement will probably be temporary, although the results this far are encouraging.—*Edward L. Compere, M.D., Chicago, Illinois.*

Leontiasis Ossea Complicated by Marjolin's Ulcer. Observation of a Case for Twelve Years. R. E. Burger and E. P. Lehman. *Surgery,* XVI, 542, 1944.

Unusual pathological conditions should be studied and then reported for the benefit of the medical profession. This article by Burger and Lehman reports the case of a patient with leontiasis ossea, whom they have observed for twelve years.

The etiology of this rare condition is not known. The patient reported was twenty-eight years of age when he developed an extensive and painful swelling over the mandible, and a salivary fistula. Treatment consisted of surgical excision and x-ray therapy. Later the patient returned with a marked increase in the size of the tumor which was not sclerotic and involved the base of the skull and the upper cervical vertebrae. There was a large area of epidermoid carcinoma, with ulceration which was typical of Marjolin's ulcer.

—*Edward L. Compere, M.D., Chicago, Illinois.*

Pantopaque. George M. Wyatt and Roy G. Spurling. *Surgery,* XVI, 561, 1944.

Wyatt and Spurling have reviewed the observations on six patients at the Walter Reed General Hospital when pantopaque was used as a contrast medium for myelography. In their opinion, although there is definitely some tissue reaction to pantopaque, the small amount of the material that is left permanently is of little consequence. Among the advantages of pantopaque is the fact that it is absorbed from the subarachnoid and the subdural spaces, and, since it is more fluid than the other contrast media, it fills smaller spaces and makes diagnostic myelography more accurate.—*Edward L. Compere, M.D., Chicago, Illinois.*

An Analysis of the More Important Orthopedic Information. Presented at the Twelve Regional Fracture Orthopedic Conferences of the Army Air Forces. Sponsored by the Air Surgeon Oct. 18 to Nov. 27, 1943. Alfred R. Shands, Jr. *Surgery,* XVI, 569, 1944.

Colonel Shands has again demonstrated his remarkably acute powers of observation and ability to coordinate information in this analysis of orthopaedic information which was presented at a series of regional fracture conferences of the Army Air Forces. In the twelve conferences, 196 papers were presented.

The material presented has been divided into anatomical groups. Shands has analyzed the methods and results of treatment of fractures and dislocations about the shoulder in part one; fractures and dislocations of the arm, forearm, and the elbow in part two; fractures and dislocations of the hand and the wrist in part three; fractures and dislocations of the hip, the thigh, and the knee in part four; fractures and dislocations of the leg and the ankle in part five; fractures and dislocations of the foot and the toes, part six; fractures and dislocations of the spine and the pelvis, part seven; compound fractures, part eight; conditions involving the back, part nine; conditions involving the knee, part ten; conditions involving the foot, part eleven.

After reviewing the material which was discussed, he has added a comment in which he expresses his own opinion and suggestions. This material is extremely interesting and instructive. It is already so condensed that it is impossible to attempt to abstract the paper itself. Every physician who is concerned with the problems of either traumatic surgery or the more everyday complaints of backache or painful feet, should avail himself of the opportunity of reading and studying the material which is presented in this excellent article.—*Edward L. Compere, M.D., Chicago, Illinois.*

Fractures of the Carpal Scaphoid in the Canadian Army. J. C. Dickison and J. G. Shannon. *Surgery, Gynecology and Obstetrics,* LXXIX, 225, 1944.

This is a study based on 257 cases of carpal scaphoid injuries collected from the Canadian Army overseas in a three-year period.

Union occurred in all cases of simple fresh waist fractures in twelve and a half weeks. Of six waist fractures with displacement of fragments, two united and four did not. In simple fresh proximal pole fractures diagnosed early, twenty weeks were required for union, the relative incidence of non-union was higher, and avascular necrosis was more prevalent.

No matter how astute the medical profession may become in the early diagnosis of fractured scaphoids, the late cases will always be present. So-called "sprained wrists" with roentgenograms negative for fracture should always be re-examined roentgenographically in two to three weeks. Among the late cases it was interesting to note that no fracture united in which diagnosis was made later than nine months after injury, and also that the fractures in which immobilization was continued for the longest periods without succes-

gave the poorest results. The late cases were treated by immobilization, by operation, or received no treatment, depending upon the judgment of the attending surgeons. How to obtain union consistently in these fractures, diagnosed so late, is still an unsolved problem. In severe disability, wrist fusion is still the last resort for the surgeon.—*Carroll B. Larson, M.D., Boston, Massachusetts.*

PERILUNAR DISLOCATION OF THE CARPAL BONES AND DISLOCATION OF THE LUNATE BONE. W. Russell MacAusland. *Surgery, Gynecology and Obstetrics*, LXXIX, 256, 1944.

The purpose of this writer was threefold: (1) to emphasize again the importance of early diagnosis and treatment, (2) to describe in simple form the dislocations which concern the lunate bone, and (3) to present the observation and results in a series of twenty-four cases. There is general agreement that immediate manipulative reduction is the treatment of choice in fresh dislocations,—that is, in those less than two weeks old. Operative intervention is indicated (1) in fresh dislocations where there is a great deal of damage to the joint structures or to the median nerve, and (2) in cases of more than two weeks' standing. Operative replacement should not be attempted in a case of more than six weeks' standing.

A detailed end-result analysis is given in nineteen cases, and it was concluded that early manipulative treatment gave excellent results. Excision of the lunate, on the whole, resulted in a useful wrist. The majority of patients complained of weakness of the hand, and were unable to make a tight fist. Dislocations of the lunate of more than six weeks' standing are best treated by operative excision. The author states that the series fails to provide sufficient material on operative reductions to permit judging the relative value of operative replacement and excision of the bone.—*Carroll B. Larson, M.D., Boston, Massachusetts.*

THE RÔLE OF THE NUCLEUS PULPOSUS IN THE PATHOGENESIS OF SO CALLED "RECOIL" INJURIES OF THE SPINAL CORD. Fritz Cramer and Francis J. McGowan. *Surgery, Gynecology and Obstetrics*, LXXIX, 516, 1944.

The authors have used the evidence available in one case of cord injury to present a new concept in the pathogenesis of lesions of the spinal cord, where no associated bone or ligamentous discontinuity is demonstrable. They believe that a violent protrusion of the intervertebral disc, by means of the hydraulic ramlike action of the nucleus pulposus when subjected to intense compressive force, causes the damage to the spinal cord. Autopsy findings in the one case showed the cord almost severed at a level directly opposite a sharp protrusion of the fifth cervical disc, while no abnormal vertebral protrusion, nor gross tearing of any posterior ligaments could be demonstrated.—*Carroll B. Larson, M.D., Boston, Massachusetts.*

TOTAL AND PARTIAL PATELLECTOMY. Bernard N. E. Cohn. *Surgery, Gynecology and Obstetrics*, LXXIX, 526, 1944.

This was a well organized and controlled experimental study of total and partial patellectomy, performed on normal healthy rabbits. The results quite conclusively showed that total patellectomy, in either adult or immature rabbits, caused early degenerative changes of the tibiofemoral articulation, most marked in the adult rabbits. Partial patellectomy produced early degenerative changes of the femoral condyles in adult rabbits, but not in younger animals. In no case of total or partial patellectomy of adult or immature rabbits was there any clinical aberration of function. These facts led the author to conclude that total patellectomy should be undertaken in humans only when such procedure cannot be avoided.—*Carroll B. Larson, M.D., Boston, Massachusetts.*

HERNIATION OF MUSCLES OF THE LEGS. H. C. Goldberg and G. W. Comstock. *War Medicine*, V, 365, 1944.

This paper presents a brief review and discussion of the question of various kinds of hernias. The authors have classified hernias in general into two groups: those which are produced as a result of a congenital defect, and those which occur secondary to extensive pressure or atrophy, due to occupation or age. Muscle hernias may be constitutional or traumatic. Serious illness, local ulceration, or hypertrophy of muscles may be factors in the production of this entity. Most muscle hernias, however, result from sudden violence, and must be differentiated from lipoma, hematoma, tuberculosis, varices, and what the authors call "pseudohernia".

One diagnostic characteristic of muscle hernias is the fact that they can be reduced through the fascial defect and will disappear when the muscle contracts, while in the pseudohernia or rupture of the muscle, the bulge may become larger. Muscle hernias also tend to disappear on passive extension, a finding which is not present in thrombophlebitis and varicose veins.

The symptoms of muscle hernias include pain at the site of the lumps, associated with use of the muscles, and there may also be tenderness after exercise. The authors report one case and advise closure with a strip of fascia lata.—*Edward L. Compere, M.D., Chicago, Illinois.*

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THE TREATMENT OF MALUNITED COLLES'S FRACTURES *

BY J. S. SPEED, M.D., AND ROBERT A. KNIGHT, M.D., MEMPHIS, TENNESSEE

From the Willis C. Campbell Clinic, Memphis

Surgical intervention is not required in all malunited Colles's fractures, especially in the milder cases. In a typical malunion of mild degree, there is a slight shortening of the radius with a mild dorsal angulation of the distal radial articular surface, but there is no derangement or involvement of the distal radio-ulnar joint. Patients will usually develop a painless, strong, useful hand and wrist, if adequate physical therapy is given, and if persistent active use of the part is continued.

Patients with malunited fractures accompanied by marked osteoporosis, fibrosis of the fingers and hand, and associated trophic changes of appreciable degree, are not satisfactory candidates for corrective surgery, and should have intense and prolonged physical therapy before any surgery is done. Otherwise, the patient will be unable to make use of the functional improvement which may be afforded by the correction of the malunion. It is only after the stiffness and pain have largely disappeared and the trophic and circulatory conditions have improved that surgery can be safely employed.

It should be kept in mind that, after a period of two weeks or more has elapsed following the fresh fracture, the use of manipulation alone to improve position of the fracture is not wise. In such a case, especially if the patient is elderly and osteoporosis is present, there is danger that manipulation will further comminute the fragments and fail to break up the impaction.

OPERATIVE CORRECTION OF MALUNION

In a study of sixty cases of malunited Colles's fracture in which surgical procedures have been employed, it is evident that no one type of corrective procedure is applicable in all instances. The type of procedure employed varies with the type of deformity and the degree of displacement. The objectives to be obtained by surgical correction are: (1) restoration of the part to as near its normal anatomy as possible; (2) improvement in the function of the part by compensatory procedures, such as resection of the distal end of the ulna; and (3) improvement in the appearance of the wrist itself.

SURGICAL APPROACH

In the earlier cases included in this study, the radial (lateral) approach to the distal end of the radius was employed. However, the dorsal approach is more satisfactory, be-

* Prepared for presentation at the Meeting of The American Academy of Orthopaedic Surgeons, January 1945, which was canceled in compliance with the request of the Office of Defense Transportation.

cause the fracture site is more easily exposed, and a more complete and direct view of the fracture is thus obtained. The approach is made in a longitudinal direction in line with Lister's tubercle, and usually extends for a distance of two to three inches (5 to 8 centimeters). It should be of adequate length, because a short exposure, even though it may be more satisfactory cosmetically, entails more vigorous retraction during the operation, and thus a greater local postoperative reaction ensues. The incision is extended through the deep fascia, and is carried down laterally between the extensores carpi radialis longus and brevis and the extensor pollicis brevis, and medially between the extensores pollicis longus and digitorum communis. Care is taken to avoid injury to the tendons and to expose the bone subperiosteally.

If excision of the ulna is indicated, a medial longitudinal approach is employed with subperiosteal exposure of the distal one to one and one-fourth inches of the ulna. The distal end of the ulna, including the styloid process, is excised by using bone-biting forceps, small rongeurs, and small, sharp osteotomes.

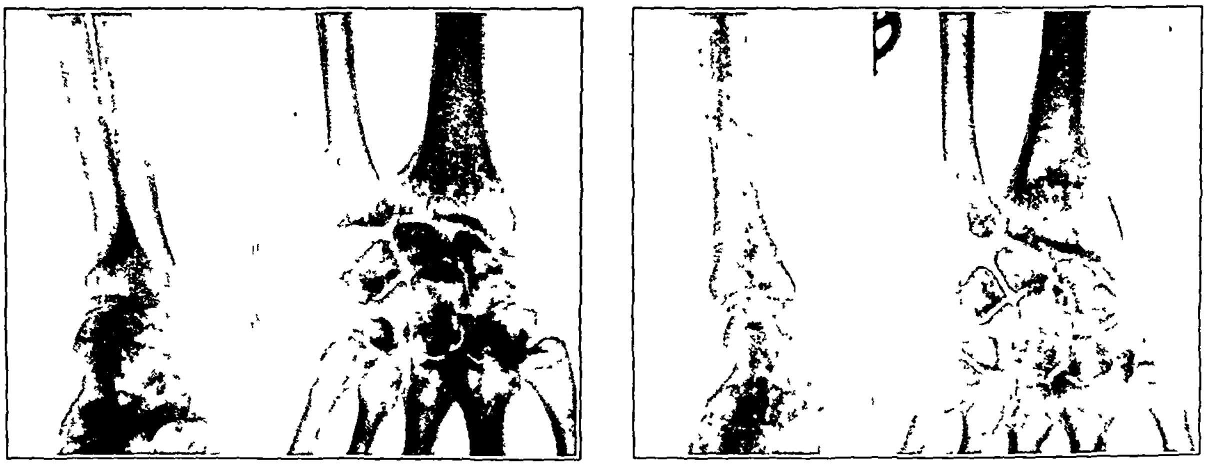


Fig. 1-A Fig. 1-B

Fig. 1-A: Mrs. J. C. R., No. 41182. Malunited Colles's fracture, with good functional but poor cosmetic result.

Fig. 1-B: Radial deformity corrected by ulnar graft, wedged into radial osteotomy site. Prominent portion of ulna was removed for cosmetic reasons and used as graft.

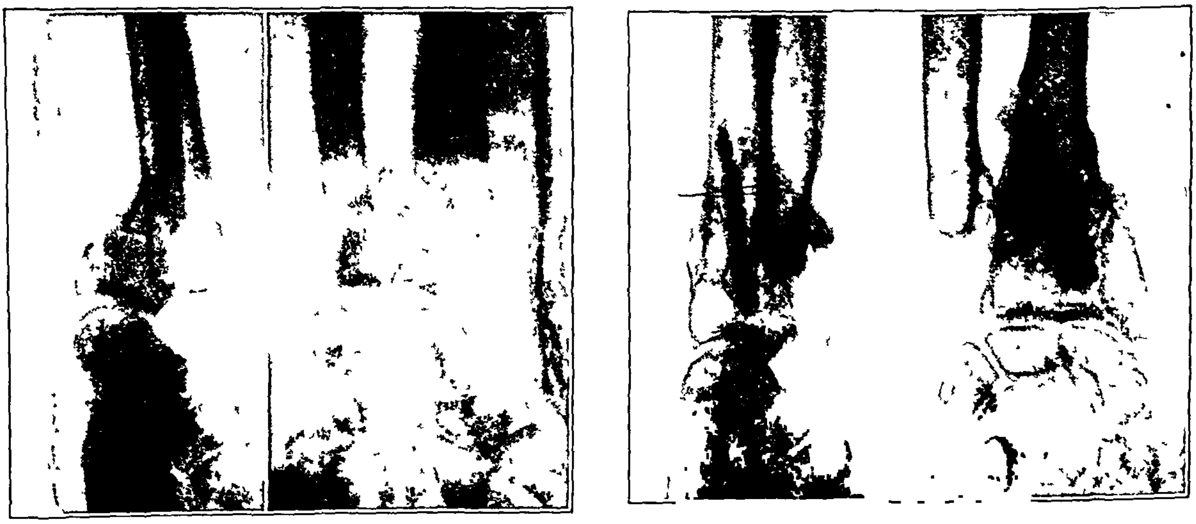


Fig. 2-A Fig. 2-B

Fig. 2-A: Mr. L. A. L., No. 57648. Unstable compound Colles's fracture with delayed union in malposition.

Fig. 2-B: Result one year after operation. Lower end of ulna was resected, permitting reduction of radial displacement; homogenous bone peg was used for stability of radial fracture. Excellent functional result; with exostosis, but not synostosis, of ulna.

SELECTION OF THE PROPER OPERATIVE PROCEDURE

Group 1

This group includes those cases in which the deformity consists chiefly of some dorsal tilting of the distal articular surface of the radius, associated with little or no radial shortening, and with no appreciable involvement of the distal radio-ulnar joint. Such fractures have usually been treated by a simple osteotomy of the radius without internal fixation. This procedure does not correct any abnormality in the relationship of the inferior radio-ulnar joint and, if such a disturbance is present, the procedure is inadequate. In this series, twenty-three such operations were done with satisfactory results in most instances, though there was partial recurrence of the deformity in approximately 20 per cent. of the cases. Recurrence took place during the period of immobilization, but in most of the cases in which it occurred, the recurrence was not of sufficient degree to impair the final result. In some instances, in addition to the radial osteotomy, the prominent medial portion of the ulnar head was removed for cosmetic reasons, without interfering in any way with the stability of the wrist.

Group 2

In those cases of malunion with broadening of the wrist due to radial shortening and associated prominence of the ulnar head, the procedure described by Campbell [1] has been used with good results (Figs. 1-A and 1-B). It consists of an osteotomy of the malunited radius at the old fracture site, a resected oblique portion of the prominent ulnar head being utilized as a graft to maintain reduction of the fracture. The removal of the prominent portion of the head of the ulna, in addition to furnishing bone for a graft, also serves to decrease the broadening of the wrist. Improvement from a cosmetic standpoint results, but radial length has not always been completely restored by this procedure.

Group 3

In many cases of malunion there is a more severe deformity than can be adequately corrected by either of the above procedures, and in such instances the use of a homogenous or autogenous intramedullary bone peg [2] for maintenance of the reduction of the osteotomized radial fragments has proved satisfactory (Figs. 2-A and 2-B). It should be stressed, however, that an intact, or at least satisfactory, distal radial surface is essential. When there is marked osteoporosis of the distal radial fragment, the use of the bone peg as internal fixation has been, in our hands, the only practical means of maintaining re-

Fig. 3-A

Fig. 3-B

Fig. 3-A: Mrs. J. M. H., No. 50351. Malunited Colles's fracture with marked deformity and moderate osteoporosis.

Fig. 3-B: Reduction was stabilized by use of homogenous bone peg. Excellent result nine months after operation, but excision of lower end of ulna may be necessary later.

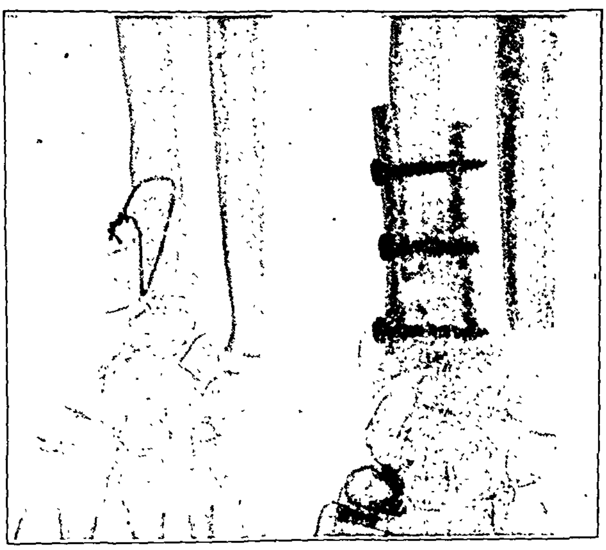
duction of the fracture (Figs. 3-A and 3-B). This procedure has also been found usefu in fresh and malunited reversed Colles's fractures, and fractures of the radial styloic with dorsal subluxation of the carpus. The bone peg acts as an internal strut to maintair the correction of the radial shortening and the dorsal angulation of the radial articula surface during the period of consolidation. If indicated, the lower end of the ulna car be excised, and the excised portion of the ulna can be used as a graft to fill in the defec at the site of the radial osteotomy, thereby making the radial fixation still more stable

The details of the procedure are as follows: A small bone peg (about $\frac{1}{8}$ by $\frac{3}{16}$ by $1\frac{3}{4}$ to 2 inches in size) is inserted obliquely through the osteotomy site into the medullary cavity of the proximal radial fragment, and on through an oblique drill hole in the media (ulnar) aspect of the radial shaft for a sufficient distance to permit reduction of the radia fracture. Then, after the fracture has been reduced satisfactorily under direct vision, the bone peg is tapped back into the shaft of the radius across the fracture site and well into

FIG. 4-A FIG. 4-B

FIG. 4-A: Mr. D. R., No. 57966. Malunion of oblique comminuted Colles's fracture, with radial shortening and ulnar prominence. Marked inferior radio-ulnar displacement.

FIG. 4-B: Result after step-cut osteotomy to gain radial length, and resection of lower end of ulna to correct discrepancy in length of radius and ulna. Resected portion of ulna was used as dorsal radial graft.



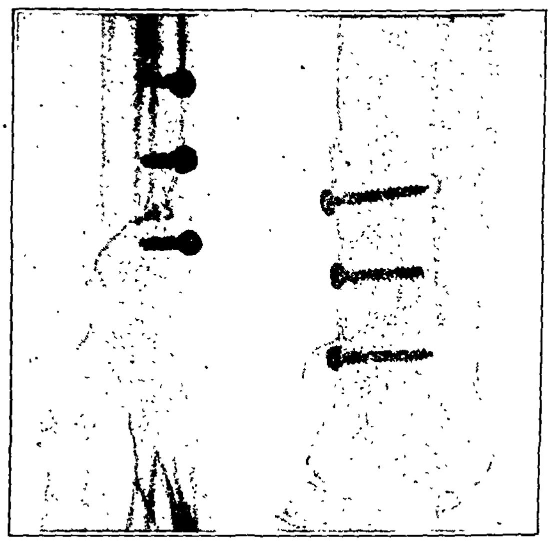


FIG. 5-A FIG. 5-B FIG. 5-C

FIG. 5-A: Mr. W. D. S., No. 50450. Non-union of Colles's fracture in malposition with marked radial shortening, following open reduction elsewhere.

FIG. 5-B: Dual bone graft employed because of osteoporosis of distal radial fragment. Lower end of ulna was resected.

FIG. 5-C: Good functional result nine months after operation.

the distal radial fragment, thereby stabilizing the reduction. Any excess portion of the proximal end of the peg is removed flush with the shaft of the radius.

Group 4. The Use of Onlay Grafts:

In one case in this series, internal fixation by means of an intramedullary bone peg did not prevent recurrence of the deformity following osteotomy. In this instance the problem was solved by utilizing a portion of the resected distal end of the ulna as a dorsal onlay graft, the graft being fixed by two vitallium screws. The result following this procedure has been quite satisfactory from both a functional and cosmetic standpoint. Similarly a second case of malunion, without previous operation, has been successfully treated (Figs. 4-A and 4-B).

In another instance a dual graft was applied (Figs. 5-A, 5-B, and 5-C). This type of fixation was indicated because of loss of bone substance with resulting non-union following an operation elsewhere. A solid union with an almost normal wrist resulted from the dual onlay graft. The pincers effect of the dual graft made possible the grasping of the distal osteoporotic fragment, and gave stability which could not otherwise have been obtained.

Group 5. Arthrodesis:

There are certain cases of severe malunion with marked deformity, where the radial fracture is situated close to the articular surface, and where there is marked osteoporosis or severe comminution of the distal radial fragment (Figs. 6-A and 6-B). In these cases it is apparent that a satisfactory movable wrist cannot be obtained, and wrist fusion is the logical solution to the problem. Usually resection of the distal end of the ulna is also necessary, because of the associated radio-ulnar disproportion and the inferior radio-ulnar traumatic arthritis which develops if the malunion is of long standing. The resected portion of the ulna can be utilized as a graft to aid in fusion of the radiocarpal articulation.

It should be kept in mind that it is not always possible to determine before operation whether an attempt at reconstruction should be made, or whether a wrist fusion should be done. This is well illustrated in the following case:

A man, thirty-three years old, was referred to the Clinic with severe bilateral Colles's fracture of six weeks' duration. At the time of operation it was felt that an attempt to obtain a movable wrist on the right was feasible, with a reasonable expectancy of a good functional result (Fig. 7-A). To date the

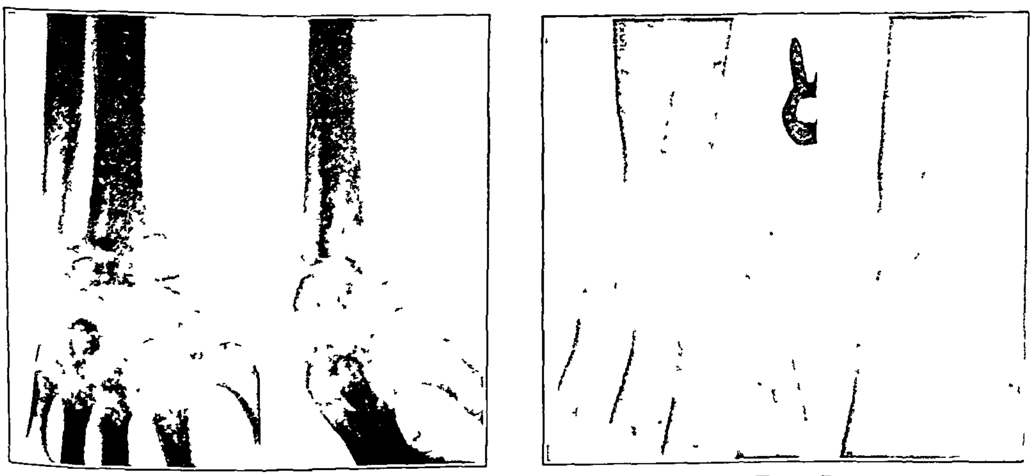


Fig. 6-A Fig 6-B

Fig. 6-A: Mr. W. K., No. 40540 Malunited Colles's fracture after failure of reconstructive procedure

Fig 6-B: Result six months after fusion of wrist. Function was much improved, despite insufficient resection of ulna.

result is quite satisfactory, though at some future time it may be necessary to fuse the wrist, if sufficient traumatic arthritis develops. On the left (Fig. 7-B), the extensive comminution of the radial articular surface necessitated a fusion, and in this case a portion of the resected ulna was used as a dorsal graft.

Group 6. Resection of the Distal End of the Ulna:

In some cases which may be classified under the heading of malunion, the chief source of disability is an inferior radio-ulnar traumatic arthritis, following a long-standing derangement of this joint (Figs. 8-A and 8-B), or following an incompletely reduced radial fracture which enters into the joint. If the reduction of the radial fracture is satisfactory, and the traumatic arthritis is the major source of disability, resection of the distal end of the ulna will suffice. This is a simple procedure, the postoperative disability is

Fig. 7-A

Fig. 7-B

This case illustrates the impossibility of determining preoperatively in every instance the exact type of reconstructive procedure which should be employed. The final decision frequently must be made at the time of operation. In this case, a reconstruction operation was accomplished in one wrist with a satisfactory functional result, while in the other, fusion was necessary.

Fig. 7-A: Mr. F. J. F., No. 61158. Right wrist: Reconstruction was possible with a reasonable expectation of obtaining a satisfactory functional result; however, subsequent traumatic arthritis may eventually necessitate fusion of the wrist. Result is satisfactory to date.

Fig. 7-B: Left wrist: Extensive comminution of the distal radial fragment necessitated primary wrist fusion, the resected portion of the ulna being used as a graft.

slight and of short duration, and the end result following the use of this procedure in properly selected cases is gratifying.

The possibility of reformation of the ulna after subperiosteal resection should be kept in mind, especially in the case of young adults and children. In these patients it is wise to excise the ulna extraperiosteally, since such bone reformation has occurred in some instances. In older adults and in the aged, this precaution has not been found necessary.

Postoperative Care

The postoperative care following surgical correction of a malunited Colles's fracture is quite similar to the postreduction care of a fresh fracture. One must not be satisfied with an unstable reduction for, not infrequently, recurrence of the deformity will take place in such cases. It is for this reason that the use of some form of internal fixation, whether a bone peg or an onlay graft, is advocated in all but the simplest of malunions.

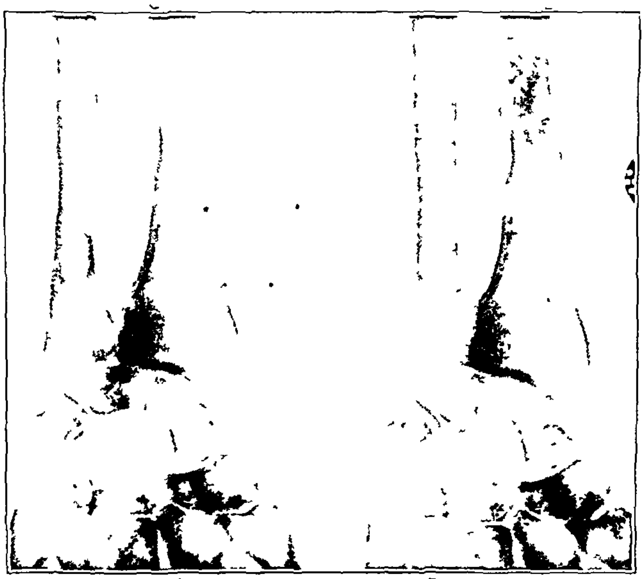


FIG. 8-A FIG. 8-B

FIG 8-A: Mr. O. R, No 59369. Old fracture of distal end of radius, with injury of inferior radio-ulnar articulation. There was severe disability, due to pain in radio-ulnar joint.
FIG. 8-B: Resection of distal end of ulna completely relieved pain and disability.

Immobilization of the wrist should be maintained until union is complete, both clinically and roentgenographically, for otherwise recurrence of the deformity must be anticipated.

CONCLUSIONS

If malunion of a Colles's fracture is present to any material degree, surgical reconstruction offers an excellent chance of improving the appearance and function of the wrist. No single type of treatment is applicable in all cases, but the procedure must be chosen for each case, depending upon the exact lesion present.

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SURGICAL ANATOMY OF THE FLEXOR TENDONS OF THE WRIST

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In surgery of the volar aspect of the wrist with its many tendons, the median nerve, and the two large arteries, precise knowledge of the relative position of these structures is important.

Even the experienced surgeon may find it difficult to recognize these structures. No wonder that occasionally, on reoperation in this area for previously performed sutures of tendons, the median nerve may be found united with a flexor tendon, the two having been erroneously sutured together.

A review of textbooks of anatomy and surgical literature shows that there is no detailed description of the relative position of the tendons of the wrist. As an example, Lewis, in Gray's Anatomy, in relation to these tendons, states only that the flexor digitorum sublimis, passing beneath the transverse carpal ligament, forms two pairs of tendons, the superficial pair going to the middle and ring fingers, the deep pair to the index and little fingers. There is no mention of the relation to the deep flexors or to the median nerve.

The present study was undertaken in an effort to discover whether or not there is a constant surgical relation of the superficial and deep flexors of the fingers to the median nerve and to the flexors of the wrist.

Observations were made on forty hands dissected by the writer, on sixty hands dissected by medical students during their regular instruction in the Department of Anatomy of the College of Physicians and Surgeons, and also on wrists operated upon by the writer during the past five years.

As a result of this, it became evident that there is a relatively constant relation between the tendons of the flexores sublimis and profundus to the index finger with the median nerve and with the tendon of the palmaris longus. This constant interrelation varies mostly in the presence of muscle or tendon anomalies.

The purpose of this article is to show the commonly encountered relation and to describe the variations of the tendons and the nerve that are important from a surgical viewpoint, as found in the literature (Testut, Le Double), and as seen occasionally by the author.

Anatomically the wrist is not a well-defined region. It may arbitrarily be confined between two transverse planes,—the proximal plane passing through the tip of the styloid process of the ulna, perpendicular to the long axis of the forearm, and the distal plane passing through the tubercle of the scaphoid and a point just distal to the pisiform bone.

In dissection from the volar surface to the deeper parts of the wrist, the superficial fascia first presents itself. Here are located the superficial veins, and the terminal branches of the medial antibrachial cutaneous nerve on the ulnar side, and the lateral antibrachial cutaneous nerve on the radial side. The palmar cutaneous branches of the radial, median, and ulnar nerves are seen emerging through the deep fascia.

The deep fascia is more dense in this region than the fascia of the forearm, especially in the distal part of the wrist.

The tendon of the palmaris longus can be seen and felt through the deep fascia in the mid-line of the wrist. The fascia forms a complete sheath for this tendon.

Slightly more radially and somewhat deeper may be seen the tendon of the flexor carpi radialis, which runs its course from the elbow to the wrist. The tendon of the flexor

carpi radialis is also completely enclosed in the deep fascia. The anterior layer of this fascia forms a much thicker cover than that formed by the anterior layer of the fascia for the palmaris longus.

The removal of the deep fascia for exposure of the subjacent structures is not easy, because it adheres to the most proximal part of the tendon sheaths of the flexores carpi ulnaris and radialis, which emerge from under the transverse carpal ligament, and also because the fascia is reinforced in this region by transverse fibers which form the superficial volar carpal ligament of the wrist.

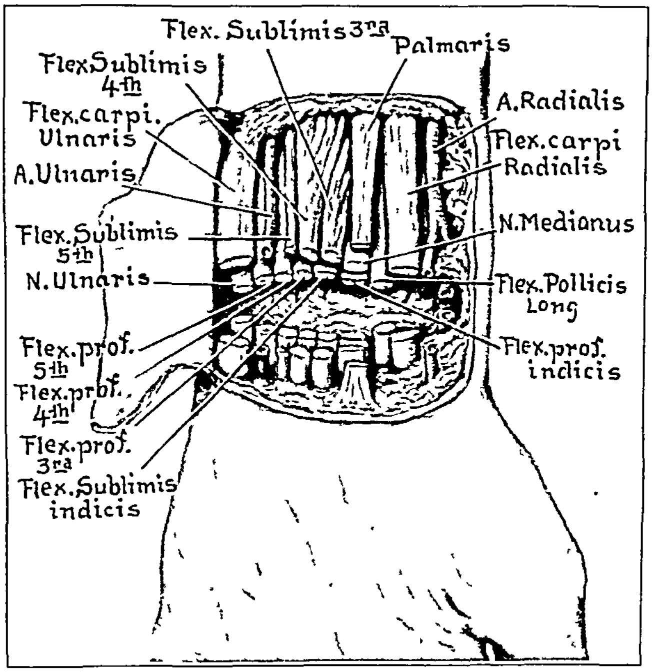

FIG. 1
A dissection of the anterior aspect of the wrist combined with a cross section of the flexor tendons and the median nerve.

The complete removal of the fascia and clearing of the tendon sheaths slightly change the normal relation of the tendons and the nerve. Cross-section studies, in addition to regular dissections, are therefore important.

To facilitate the description, an anterior dissection, combined with a cross section of the flexor aspect of the wrist, is presented (Fig. 1).

The tendon of the palmaris longus is normally in the mid-line of the wrist, continuing its course from the ulnar side of the humerus to the palmar aponeurosis.

To the ulnar side of the palmaris longus, on a slightly deeper plane, appears the flexor sublimis tendon to the middle finger; it is usually of considerable size. This tendon shows on its radial side fleshy fibers, arching in a proximal and lateral direction. On the ulnar side, this tendon is devoid of fleshy fibers for a much longer distance. Contiguous to it and on its ulnar side appears the flexor sublimis tendon to the fourth finger; medial to it, slightly deeper but intimately close, is found the flexor sublimis to the fifth finger. This last tendon is sometimes concealed under the ulnar artery which in its turn is covered by a double layer of the deep fascia, as shown in the complete schematic cross section (Fig. 2).

To the radial side of the palmaris longus is located the tendon of the flexor carpi radialis, and lateral to it appears the radial artery.

When the tendon of the palmaris longus is elevated and slightly retracted to the ulnar side of the wrist, and the fascia underneath is cleared, immediately under the tendon is found the median nerve. The nerve is located approximately in the same horizontal plane and to the radial side of the flexor sublimis tendon of the middle finger before it enters the carpal tunnel. At the proximal limit of the wrist, the median nerve is dorsal to the arching fleshy fibers of the same tendon. Here it almost constantly appears from underneath the arching fibers to continue its further course through the wrist to the palm.

When the median nerve is elevated and retracted to either side, the tendon of the deep flexor of the index finger is most commonly found under the median nerve.

To the radial side of the median nerve and the tendon of the flexor profundus indicis, in the space between these two structures and the tendon of the flexor carpi radialis, but dorsal to this last tendon, is found the tendon of the flexor pollicis longus.

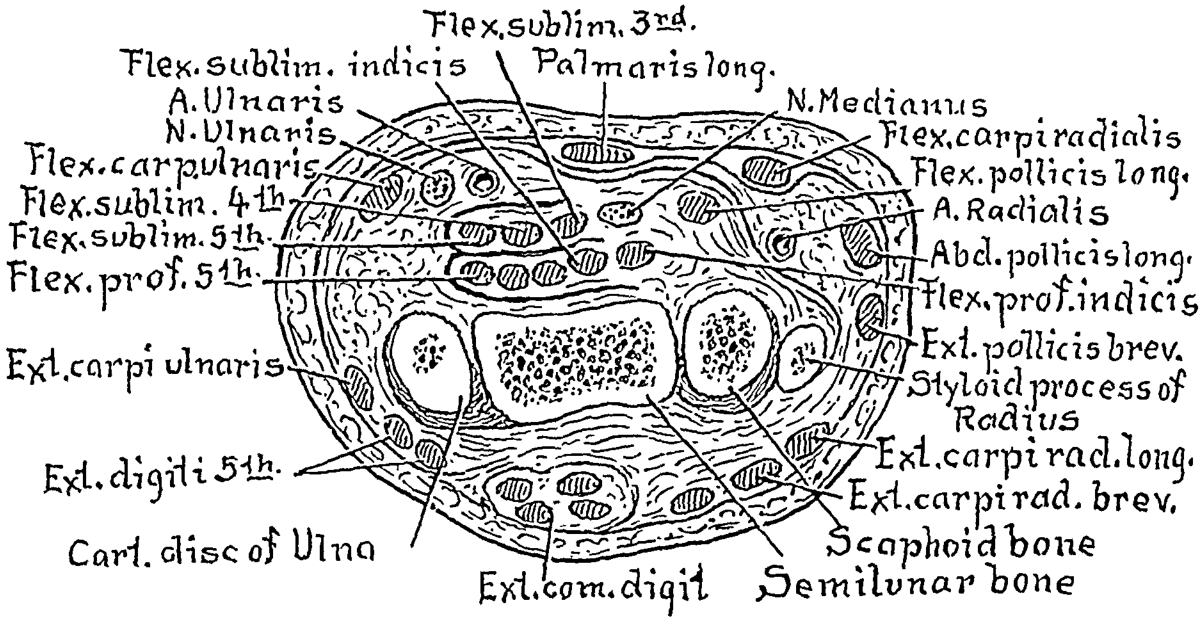

Fig. 2

A complete cross section of the right wrist. The distal segment of the section shows diagrammatically the relations of the tendon of the palmaris longus to the median nerve, to the flexor profundus indicis, and to the other flexor tendons of the fingers and wrist.

To the ulnar side of the deep flexor to the index finger, and slightly more anteriorly but underneath the tendon of the flexor sublimis to the middle finger, is found the tendon of the flexor sublimis to the index finger. To the ulnar side of the tendon of the flexor sublimis indicis are found the deep flexors to the middle, fourth, and fifth fingers. These last are approximately on the same level as the tendon of the flexor sublimis indicis, and are placed very close together, so close that sometimes they cannot be separated completely.

In a cross section of the wrist in which the plane of section passes through the styloid process of the radius and a point just proximal to the pisiform bone, the relationship of the tendons and nerve is shown. The diagrammatic illustration represents the distal part of the right wrist (Fig. 2).

This illustration shows that, in the average hand, the tendon of the palmaris longus can be considered as a key to the deeper structures. It leads in depth to the median nerve which is under the tendon of the palmaris longus, to the tendon of the flexor profundus indicis found under the median nerve, and to all the other tendons in their proper relation to the radial and ulnar side of the central column.

It may be noticed that the location of the deep flexor to the index finger does not change, whether the ulnar bursa (common flexor tendon sheath) includes the index flexors, or whether the index flexors have an independent sheath.

The tendons of the wrist present frequent variations which are a part of the variations of the muscles of the forearm. The complete description of these variations is beyond the limits of this article. To understand the variations it is important to know that they are not haphazard, but are an expression of differentiation of a common volar muscle mass, subject to definite developmental rules.

According to Lewis, in the human embryo, the development of the muscles of the anterior surface of the forearm begins as a common mass which gradually recedes from the wrist proximalward and splits into longitudinal units to form the adult muscles and tendons.

Considered from the viewpoint of comparative anatomy, the muscles of the volar aspect of the forearm form a common flexor-pronator group, originating from the medial epicondyle of the humerus, the ulna, and the radius, as an undifferentiated mass, which splits into distinct longitudinal units. The splitting and the development of the con-

stituent parts vary in accordance with the functional development of the hand of the corresponding group. Thus, in the reptilian hand, which moves as a unit without separate finger or wrist motion, the volar musculature of the forearm is said to be undifferentiated and undivided almost in its entirety. In man, the known complexity of the volar musculature is in full accordance with the functional demands of the human hand. In the intermediate groups, a wide range of combinations and divisions represent normal patterns for the corresponding group. Testut has shown that the human muscle variations often represent a modified form of a normal pattern, seen in a lower zoological group.

Most of the variations fall into definite groups and for simplicity are considered separately for each terminal group of tendons.

1. The Flexor Carpi Radialis

In this group there are:

a. Frequent insertion of the flexor carpi radialis into the greater multangular.
b. Insertion into the greater multangular and the scaphoid.
c. Insertion into the base of the metacarpals.
d. Insertion into the transverse carpal ligament.

While the first three insertions do not materially change the relation of the tendon, the fourth places the tendon more superficially and may lead to its confusion with the tendon of the palmaris longus, especially when the palmaris longus is absent.

2. The Palmaris Longus

a. The palmaris longus is absent in about 11 per cent. of cases according to Le Double. In the absence of this tendon, the author observed, in three instances, that the flexor sublimis indicis appeared between the median nerve and the tendon of the flexor sublimis to the middle finger.

b. The tendon may divide into two or three separate tendons.

c. Instead of a tendon, a muscle belly may be found.

d. The tendon may deviate from its mid-line position in the wrist to the ulnar side and become inserted into the pisiform bone, or into the abductor pollicis brevis.

3. The Median Nerve

Hovelacque found that a frequent variation of the median nerve is in its splitting into two longitudinal trunks. Occasionally, the nerve occupies a slightly ulnar position in relation to the palmaris longus, or shifts to a more lateral location in relation to the palmaris longus.

The flexors of the fingers and the thumb produce variations which are frequently interrelated.

4. The Flexores Digitorum Sublimis and Profundus

a. There is frequent extensive fusion of the tendons of the flexores sublimis and profundus to the fourth and fifth fingers.

b. Frequently there are accessory muscle and tendon slips to the flexor profundus and especially to the flexor profundus indicis.

In one of the dissected specimens, a supernumerary tendon of this type was found in both wrists. For experimental purposes, the normal flexores digitorum profundus and sublimis were completely severed in the wrist. The accessory slip originated in the distal part of the origin of the flexor pollicis longus and was inserted into the tendon of the flexor profundus indicis, near one of the lumbricales. Traction applied to the accessory slip produced flexion of the index finger.

c. The flexor sublimis to the fifth finger and to the index finger may be absent.

d. The flexor profundus to the index finger may be split into two independent tendons.

c. The flexor profundus indicis may have a common origin with the flexor pollicis longus.

5. The Flexor Pollicis Longus

a. The flexor pollicis longus may be absent, as normally observed in some of the great apes. The thumb is then found very much diminished in size.

b. The tendon may be divided into two or three separate slips with insertion into the scaphoid or into the transverse carpal ligament.

6. The Flexor Carpi Ulnaris

a. In the flexor carpi ulnaris, *the tendon of insertion into the pisiform bone may become double.*

b. It may fuse with the tendons of the flexor sublimis or flexor profundus.

c. The insertion may descend to the fourth or to the fifth metacarpal.

Figures indicating the incidence of the individual variations are nót given, because they are not definitely available in the literature, and also because a specially conducted investigation on a large scale is required for definite conclusions. Nevertheless, the description of the most common variations is important as they are comparatively frequent, they form an integral part of the anatomy of the wrist, and they are necessary for proper surgical orientation in this region.

SUMMARY

The relative position of the flexor tendons and the median nerve is not adequately described in the literature. A study of the wrist showed a comparatively constant relation of the tendon of the palmaris longus to the median nerve and tendon of the flexor profundus indicis.

The anatomy of the tendons of the wrist and of the median nerve, as commonly observed, and also the surgically important variations of the tendons are presented.

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strip of fascia lata, about six inches long and three inches wide. The length of this graft can be determined by measuring the distance between the tip of the scapula and the severed tendon of the pectoralis major, always allowing sufficient length to permit suturing of the graft to the tendon and looping through the hole which has been drilled in the scapula. The graft is then rolled around the tendon of the pectoralis major to form a tube of several layers' thickness and overlapping the tendon about one inch. It is then securely sutured with silk. The edge of the fascial tube is also sutured upon itself with a running stitch. It is important that the gliding surface of the fascia be also the gliding or superficial surface of the fascial tube. This tube is then passed from the anterior incision through a subcutaneous tunnel to the posterior longitudinal incision over the tip of the scapula. It is looped through the hole in the scapula, pulled taut, and sutured upon itself. During all of this procedure, the scapula should be held depressed against the chest wall and rotated anteriorly. All incisions are closed in the usual way. The arm is immobilized at the side by strips of adhesive tape or a Velpeau bandage. Cautious motion may be started in three weeks.

CASE REPORTS

Case 1. G. R., male, twenty-three years old, was first seen in December 1939 with a history of pain in the region of the right shoulder in June 1938. When seen, his only complaint was one of fatigue in the shoulder and arm. Physical examination showed the boy to be in good condition, except for the right shoulder which revealed the usual objective findings of a paralyzed serratus anterior, with marked winging of the scapula. All other muscles of the shoulder girdle and upper extremity were functioning normally. Reflexes were normal. A diagnosis of residual deformity from infantile paralysis was made.

The operation as described was performed upon this patient. He made an uneventful recovery, and was discharged from the hospital in five days. Three weeks later the immobilizing dressing was removed, and gentle motion, both active and passive, was started. At that time, the transplanted pectoralis major could be felt to contract strongly on voluntary effort, and a firm cord representing the fascial graft could be seen and felt, running transversely across the axilla to the tip of the scapula. The patient was seen at intervals for several months, and when last seen, scapular movement was normal. The right scapula was slightly more prominent than the left, but was not as conspicuous as it had been. The graft and transplant were functioning excellently. The patient returned to work, and

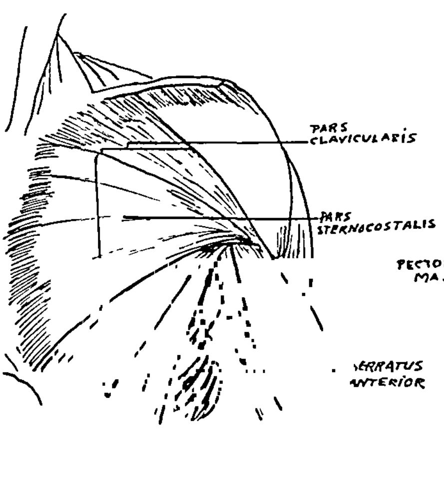

Fig. 2-A

Anterior surface of the chest with muscles intact, to show direction of fibers of pectoralis major.

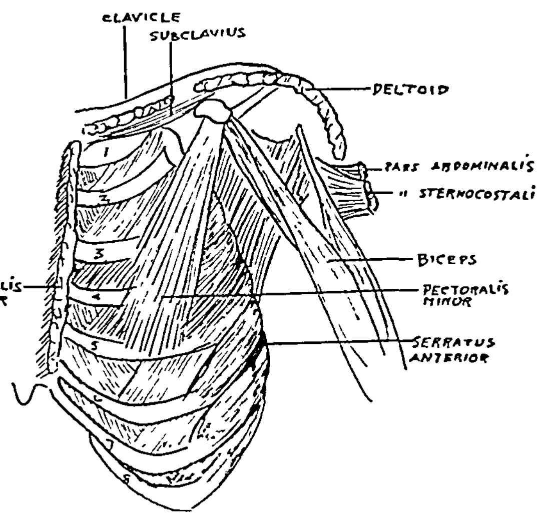

Fig. 2-B

Anterior chest wall with pectoralis major removed, to show the fibers of the serratus anterior and of the pectoralis minor.

it is interesting to note that he later passed the physical examination for the Navy, and has served throughout the War.

CASE 2. A. N., female, twenty-eight years old, was first seen in January 1942. She complained of a prominent right shoulder blade which was cosmetically embarrassing. The patient had had infantile paralysis in childhood. Examination was negative except for the prominent right scapula and loss of power in reaching forward, indicating paralysis of the serratus anterior. Evidence of any central nervous disease was lacking. The patient was operated upon, and kept under observation for six months. The scapula was held close to the chest wall and was nearly normal in movement. The cosmetic result was satisfactory.

A procedure similar to the one described and based upon essentially the same principles was reported by Tubby in 1904. He inserted "the cut end of the pectoralis major into as much of the width of the serratus magnus as possible, and this was done by dividing the cut end of the pectoralis into several fasciculi, then, drawing the paralysed serratus well forward, the fasciculi of the pectoralis were firmly stitched with silk to the serratus magnus over an area corresponding to four or five of the digitations of the latter". The objection to this procedure is the dependence of the pull of the transplanted pectoralis major on a paralyzed, atrophic serratus, which might easily be stretched. While the immediate result of the operation might be satisfactory, the late result might reasonably be expected to be unsatisfactory. (After this paper had been submitted to *The Journal*, the author learned that Ober had operated on two cases, using a procedure similar to that here described by the author.) Dickson has described the use of a fascial transplant from the inferior border of the pectoralis major to the inferior border of the scapula. This would immobilize the lower angle of the scapula, but would probably produce little scapular motion. Whitman fastens the vertebral border of the scapula to the spinous processes of the fourth, fifth, sixth, and seventh thoracic vertebrae by strips of fascia lata.

The operation described fulfills the requirements for such a procedure. The utilization of a portion of the pectoralis major as a substitute for a paralyzed serratus anterior is logical, since the pull of the two muscles is parallel (Fig. 2-B). The pectoralis major abducts and draws the arm forward, and the serratus draws the scapula forward. One should expect the transplanted pectoralis to have little difficulty in becoming adapted to its new function. Lastly, the normal function of the arm and shoulder which is seen following radical mastectomy, in which both pectoral muscles are removed, leads to the conclusion that a portion of the pectoralis major can be sacrificed as an adductor of the arm without interfering with the function of the arm.

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THE TREATMENT OF NON-UNION OR DELAYED UNION OF FRACTURES BY MEANS OF MASSIVE ONLAY GRAFTS FIXED WITH VITALLIUM SCREWS *

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The almost universally good results obtained by means of the massive onlay graft for delayed union or non-union of long bones may well be stressed at this time. However, apart from minor variations in technique, there is nothing new or original in this report.

In essence, the massive onlay graft is simply a full-thickness piece of cortex of autogenous bone applied to the surface of the fragments (across the ununited gap) but not countersunk into the recipient fragments. Union takes place between the fragments and the graft, and directly across the gap. Firm fixation is provided, which is essential.

The inlay or countersunk graft first came into general use about 1912, and since then the technique has been variously modified. For about fifteen years, it was the usual practice to prepare a specially cut bed for the reception of the bone graft—the inlay method. Then in 1927, with the publication of "The Onlay Graft in the Treatment of Ununited Fractures in Long Bones", by Campbell, and, in 1928, the article by Henderson, a new technique came into prominence. From that time on, various authors have described and perfected the onlay graft.

Different methods of fixation of the onlay graft have been suggested,[10,13,17] including aluminum, bronze and silver wire, and kangaroo tendon. With the use of these the author is not in sympathy. Miller reported the technique of onlay and inlay grafts, using removable Kirschner-wire fixation, but the risk of infection in this procedure is obvious. Bone pegs were also used, but they greatly increase the difficulty of the operation.

Vitallium screws have greatly simplified the procedure of bone grafting. Their use is now widespread in the United States and Canada and in the British Isles, and after six years there are no reports of their having had any detrimental effects on body tissues. Vitallium is sufficiently passive in body fluids to resist disintegration, and it does not release metallic ions into the tissues. It appears to be completely inert. It is extremely strong and hard. On occasion, when a plate or screws have had to be removed, they have always been found to have retained their high polish, and no harmful effects have been noted in the adjacent tissues.

FUNCTION OF A BONE GRAFT

A bone graft has at least two functions,—(1) it must provide a rigid internal fixation, and (2) it must play a physiological rôle. The graft can hardly be regarded as a "dead strut", otherwise simple plating would produce the desired effect. This might be illustrated by the fact that fractures of the neck of the femur, with the fracture line at more than 60 degrees to the horizontal plane, will not unite when transfixed by a Smith-Petersen nail unless the use of the nail is supplemented by a bone graft. Hey Groves upheld the theory of the living graft, as did Lambrinudi and Stamm. Further weight might be added to the theory of the physiological rôle by a recent personal communication from Major H. C. Blair, Medical Corps, Army of the United States, who has been applying his onlay grafts cortex to cortex, and has been gratified by the rapidity of union obtained.

Whatever the underlying principles may be, it would seem that the massive onlay

* Prepared from a paper read before the Orthopaedic Section, Royal Society of Medicine, at Ely, Cambridgeshire, England, June 13, 1942.

graft, fixed with vitallium screws, met all the requirements,—internal fixation, supplementary bone, osteogenic material, and the stimulation of osteogenesis.

RESULTS

In some 170 cases in which this method of grafting the long bones has been employed, the author has had only one failure, an old ununited fracture of the upper end of the tibia, which united successfully after a second similar graft.

This report is based on only thirty cases, of which accurate case records have been kept in the Orthopaedic Service of the Royal Air Force. A period of about two years is covered. In all, the bones grafted have united in good position. Seventeen of the patients are on full duty at their various air or ground assignments. Three are on limited service, including non-operational flying. One, who had a forearm graft and later a mid-thigh amputation, is unfit for flying. One, who had grafts of both femur and tibia, is undergoing treatment for a sciatic lesion dating from the injury. Two have been discharged from the service, and the remaining six are still undergoing rehabilitation. The site of graft and average time of fixation for this series, treated in England, are shown in Table I.

TABLE I

FRACTURES OF LONG BONES TREATED WITH ONLAY GRAFTS

Site of Fracture	Number of Cases	Average Period of Fixation
Radius	8	10 weeks
Ulna	4	10 weeks
Femur	6	4 months
Tibia	11	4 months
Humerus	1	11 weeks

The age incidence was favorable, nineteen to thirty-six, with the exception of one patient fifty-seven years old, with fractures of the forearm, in whom bone was produced at an incredible rate. Thirteen of the patients suffered fractures as the result of aircraft accidents; fifteen as the result of motorcar or motorcycle accidents; one was due to a bomb explosion; and one was the result of football injuries. Nine of the patients were under treatment on this Service from the onset of injury, while the remainder had been treated elsewhere for periods varying from one month to a year. Complications, such as skin loss, frostbite, compound wounds, and burns, were contributing factors to the delaying of union or to the malposition of fragments.

OPERATIVE TECHNIQUE

A tourniquet is used wherever possible, even in grafts of the femoral shaft. In the latter case a Steinmann pin is passed from front to back just above the greater trochanter and just inside the iliotibial band. The tourniquet is then applied around the groin and above the pin. In operations on the forearm and leg, pneumatic tourniquets are by far the most satisfactory; in the arm, pressure should be about 240 millimeters (Bunnell advises 300 millimeters). In the Campbell-Boyd type of pneumatic tourniquet, the pressure is maintained for the arm at nine pounds, and for the leg at fourteen. In the lower extremity a tourniquet applied below the upper third of the thigh is dangerous.

The operation is greatly facilitated by having two teams working, one preparing the bed for the graft and securing it in position, while the other obtains the graft. A tibial graft is decidedly preferable because it is strong enough to impart rigid internal fixation.

The Approach

The approach to the shafts of the long bones must be definitely along anatomical planes. The work of Henry on this subject is classic. No exposure of a long bone should

be made without due respect for soft tissues. The result of surgical trauma to normal structures may be serious; its avoidance cannot be stressed too strongly.

Preparation of Fragment Ends and Graft Bed

All fibrous tissue intervening between the fragments and all excess callus should be removed. Disturbance of normal periosteum should be kept to a minimum. The ends of the fragments should be freshened by removal of sclerotic bone and the medullary canals opened by drilling, if necessary. Care in properly fitting together the ends of the fragments is essential.

It is usually unnecessary to section the fibula in grafting the tibia; occasionally this has to be done. When a gap of half an inch, bridged by one or two massive onlay grafts, can be packed with osteogenic material from the medullary canal at the upper end of the tibia, supplemented by small bone chips, union may be expected. In such a case the impression of a gap may be given in the postoperative roentgenogram; actually there is no gap.

When the fragments have been accurately apposed, a bed is prepared. This is done most easily by a chisel, rather than by an osteotome. In all long bones except the tibia, the bed is prepared on the most easily available surface, having regard to such structures as the musculospiral nerve in the humerus. In the tibia, it is made over the lateral aspect of the bone. In this site the graft is covered by the extensor-muscle bellies; when placed on the flat anteromedial aspect, it is virtually subcutaneous.

Preparation of the Graft

It is preferable to select the upper end of the tibia for grafts, since in this area they seem more osteogenic. Furthermore, the nutrient artery is avoided as well as the possible subsequent development of a hematoma. Another advantage is that it provides easy access to the upper part of the medulla, the source of the semifluid cancellous material which may be easily pressed into every crevice at the recipient site. The iliac crest, probably the ideal bone graft from an osteogenic standpoint, is too malleable for this purpose.

The graft is removed from the donor tibia by the use of an electric saw. Before the graft is removed, it is helpful to bevel its edges and place the drill holes. The medullary portion of the tibial graft is removed from the cortical portion by means of a broad osteotome, the graft being firmly held, edge up, on a wooden block by an assistant. This leaves a rough contact surface.

Application of the Graft

The medullary portion of the graft is placed easily in the prepared medullary canal and the cortical portion settled in the prepared bed. After the recipient fragments have been drilled, the graft is fixed in position by means of vitallium screws of suitable length. Six screws are usually used in all but forearm grafts (where four usually suffice). Six screws give twice the stability obtained by four. The screws are "staggered", thus ensuring against torsion strain. The screws must engage both cortices of the recipient fragments. The graft can be fastened to the fragments advantageously from the uppermost drill hole downward, being held in contact with the fragments quite easily by means of one or two Lane bone holders. When the distal fragment is reached, it can be accurately apposed to the graft and maintained while it is being engaged.

Finally, all crevices are filled with material scooped from the medulla of the donor leg, the material being used like mortar. The wounds are sutured with interrupted nylon in the skin, and a padded plaster cast is applied. After fourteen days, this cast and the sutures are removed, and a non-padded cast is substituted. At the same time the sutures are removed from the donor leg and a long non-padded cast is applied. This may be

changed to a below-the-knee cast at the end of seven or eight weeks, and at the end of another four weeks a walking heel may be added. Protection for ten weeks should suffice for the donor leg, while fixation of the grafted limb in plaster is maintained until union is clinically and roentgenographically solid.

The period of external fixation found to be necessary in this series (in England) is shown in Table I.

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CORRECTION OF HALLUX VALGUS BY METATARSAL OSTEOTOMY

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Since 1922, the standard procedure at the Henry Ford Hospital for the correction of hallux valgus deformities has evolved from the original osteotomy operations devised by Hohmann and Peabody. Over a period of years several modifications of the original procedures have been adopted to improve the technique, and to correct more completely the underlying causes of the deformity.

In 1923, Hohmann reported for the first time an osteotomy operation devised for the correction of hallux valgus. It was a radical departure from the accepted bunionectomies of the time, and, although it was a sound procedure basically, there seemed to remain a number of deficiencies. The operative technique consisted of a trapezoid resection of the metatarsal shaft proximal to the exostosis, followed by reapproximation of the fragments. No attempt was made to remove the exostosis, to visualize the joint, or to excise the bursa. The adductor hallucis tendon was shortened in a further effort to prevent recurrence of the deformity. Stable internal fixation of the metatarsal fragments was not attempted.

Peabody in 1931 reported a bunionectomy, first employed in 1922, which was the forerunner of the operation we shall describe. Notable among the improvements in operative technique over that of the Hohmann operation was the use of a heavy chromic suture for internal fixation. The suture was inserted through drill holes in the apposing metatarsal fragments to prevent shifting during convalescence. Peabody also noted that a bone spicule retained on the lateral aspect of the capital fragment assisted in preventing horizontal shifting of the fragments. Other advances were the excision of the exostosis and the plastic repair of the capsule. The osteotomy employed was uniformly cuneiform, the wedge-shaped bone fragment being removed prior to approximation of the capital and diaphyseal margins. It is the authors' opinion that the theory supporting this type of osteotomy is in error, inasmuch as the basic deformity, the metatarsus primus varus, is not corrected, but is exaggerated by reapproximation of the metatarsal fragments. This would then predispose to recurrence of the deformity. It has been the tendency in the past to underestimate the significance of the congenital varus deviation of the first metatarsal in the development of the typical hallux valgus deformity. Shoes have borne the burden of the blame for many years. This "vicious shoeing" we now realize is of secondary importance, and is rarely capable of producing severe bunions unless the basic metatarsus primus varus already exists. This deformity makes the great toe more vulnerable to extrinsic influences, particularly short stockings and short, narrow shoes, which eventually produce the characteristic deformity.

The Mayo bunionectomy has withstood the test of time, and has acquired a great many enthusiastic supporters. It is essentially an arthroplasty of the metatarsophalangeal joint, which consists of resection of the cartilage-bearing surface of the metatarsal. The head is then remodeled, and a U-shaped bursal flap is turned into the joint. Since the articular cartilage is often uninvolved, we feel that this operation should not be performed indiscriminately, but should be reserved for severe deformities associated with degenerative changes within the joint. The surgical shortening of the first metatarsal is capable of producing a secondary metatarsalgia through the shifting of the burden of weight-bearing toward the lateral aspect of the foot.

The bunionectomy devised by McBride adheres to conservatism, and employs a minimum of bone surgery. Briefly the procedure consists of transplantation of the common

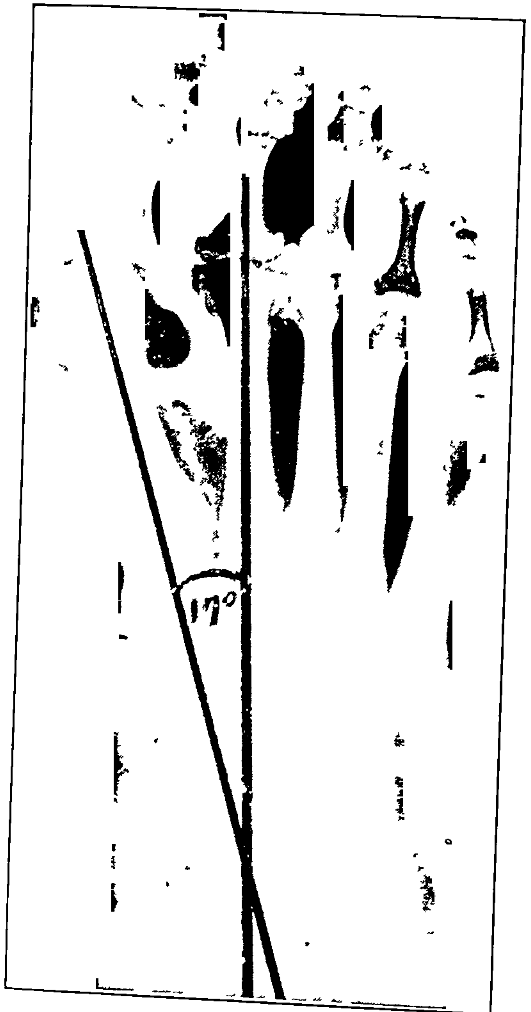

FIG. 1-A

Metatarsus primus varus of 17 degrees. Hallux valgus Grade 3. Note Freiberg's infraction.

FIG. 1-B

Postoperative roentgenogram. Varus deviation of first metatarsal, corrected to 9 degrees.

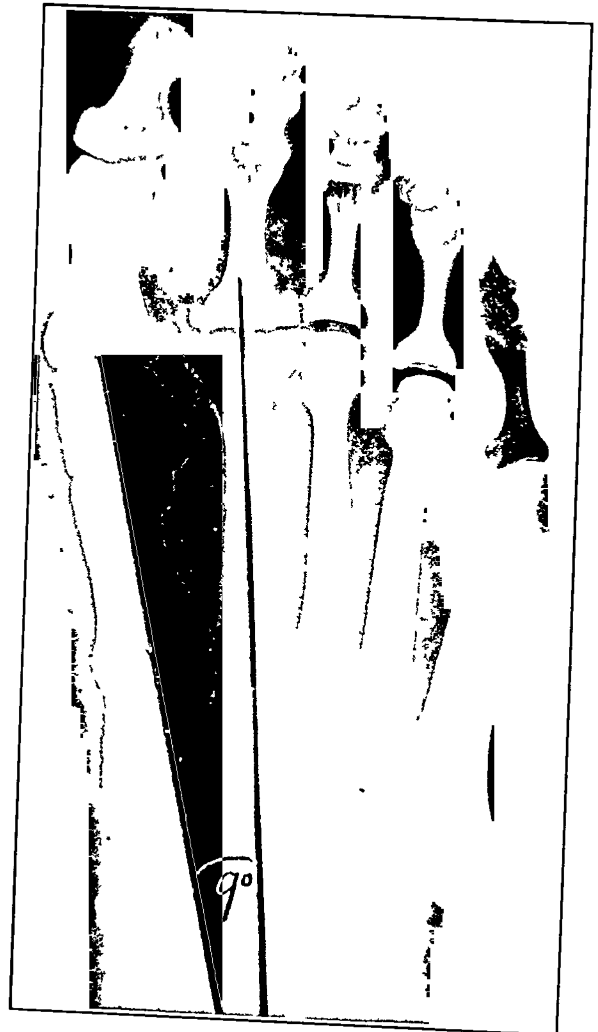

FIG. 1-C

Correction maintained at 9 degrees after two and a half years.

tendon of the adductor hallucis from the base of the proximal phalanx to the head of the first metatarsal. The external sesamoid is removed, when indicated. The bursa over the medial aspect of the metatarsal head and the exostosis are removed. Manipulation of the great toe into a position of overcorrection, and of the first metatarsal into a more lateral position is followed by application of a corrective plaster slipper. Statistically the results appear to be very satisfactory in the series of patients reported by McBride, who range in age from sixteen to seventy-one years.

It is difficult to conceive that transplantation of the relatively weak adductor hallucis muscle is capable of maintaining the first metatarsal in this more lateral position. It would seem that complete and permanent correction would necessitate an osteotomy of the metatarsal of the type described by Lapidus, or that which the authors will describe. For the sake of simplicity, we prefer the double transverse osteotomy to the formidable reconstruction of the proximal metatarsal shaft, employed by Lapidus.

Indications for the correction of hallux valgus by metatarsal osteotomy are essentially the same as those for other bunion operations. They are valgus deformity of the great toe, painful metatarsophalangeal articulation, exostosis formation, irritation of the bursa, and, more important, the metatarsus primus varus which is always present in more serious cases. In fifty-five of our cases, chosen at random, the average deviation of the first metatarsal from the longitudinal axis of the second was 13.8 degrees. The variation in the group was from 9 to 19 degrees. By means of metatarsal osteotomy it was possible to attain an average correction of 5.2 degrees, or to 8.6 degrees. The range of correction was from 1 to 11 degrees (Figs. 1-A, 1-B, and 1-C).

In another series of cases, which we shall consider normal feet, it was found that the angle of deviation of the first metatarsal varied from 2 to 9 degrees, the average being 5.6 degrees. This group of fifty patients had been under treatment for contusions or fractures of the toes, and none had complained of the symptoms associated with hallux valgus. It is our opinion that the hallux valgus deformity should be corrected by the metatarsal osteotomy in all instances where deviation of the first metatarsal is 10 degrees or more. Conversely, if the deviation is less than 10 degrees, a more conservative bunionectomy will give satisfactory relief from symptoms. In such instances, the basis of the complaint is a large exostosis over the metatarsal head, which gives the erroneous impression of abnormal deviation of the first metatarsal. In situations such as this, we have found that the technique of Silver has given very gratifying results.

Failure to obtain a satisfactory functional and cosmetic result following bunionectomy can be attributed to a great number of inadequacies of technique and errors in judgment. Most important of these are:

1. Failure to remove the exostosis adequately.
2. Damage to the articular cartilage of the involved bones, predisposing to hallux rigidus.
3. Failure to correct the metatarsus primus varus.
4. Alteration of the sesamoid-metatarsal relationship.
5. Excessive shortening of the first metatarsal, thereby altering the ratio of weight distribution. This situation has been described by Morton[9]. The short first metatarsal, whether of congenital or surgical origin, predisposes to metatarsalgia through the shifting of the weight from the first metatarsal to the heads of the second and third.
6. Failure to shorten the tibial collateral ligament.
7. Failure to employ corrective dressings for a sufficient period of time after operation.
8. Wearing of improper shoes after surgical correction.

The writers carefully observe the above precautions in performing the correction for hallux valgus, as will be evident in the detailed description of the surgical technique and after-care.

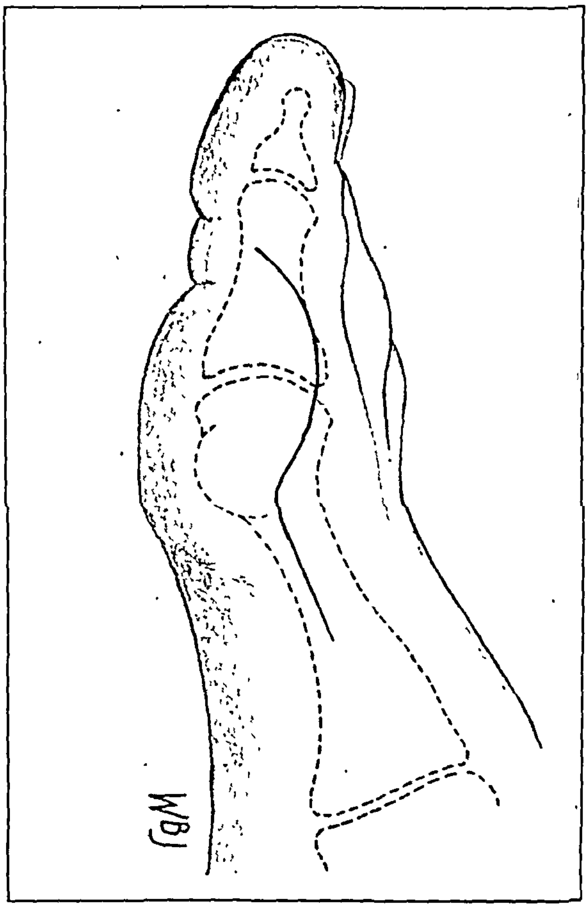

Fig. 2

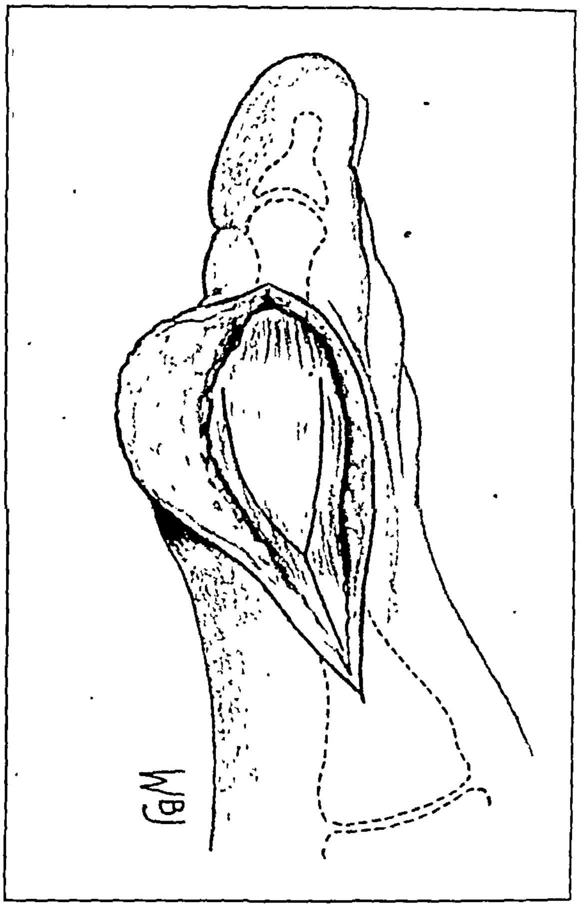

Fig. 3

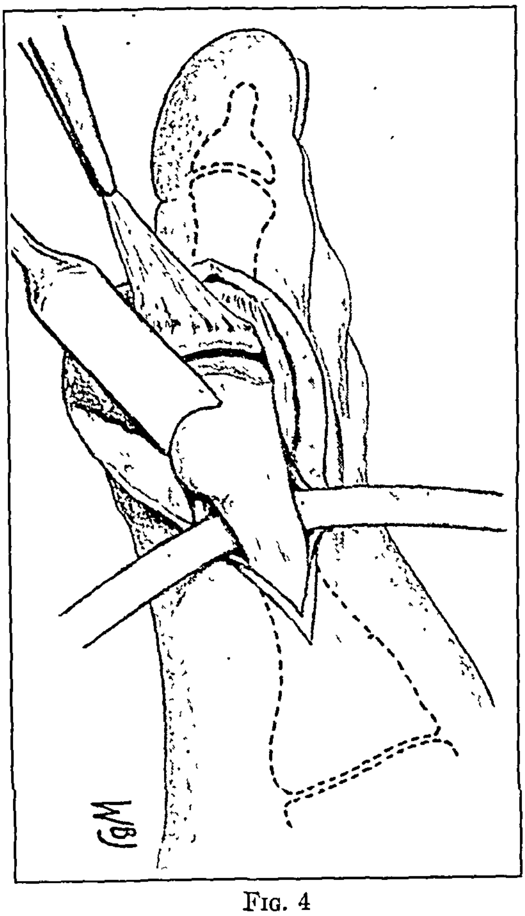

Fig. 4

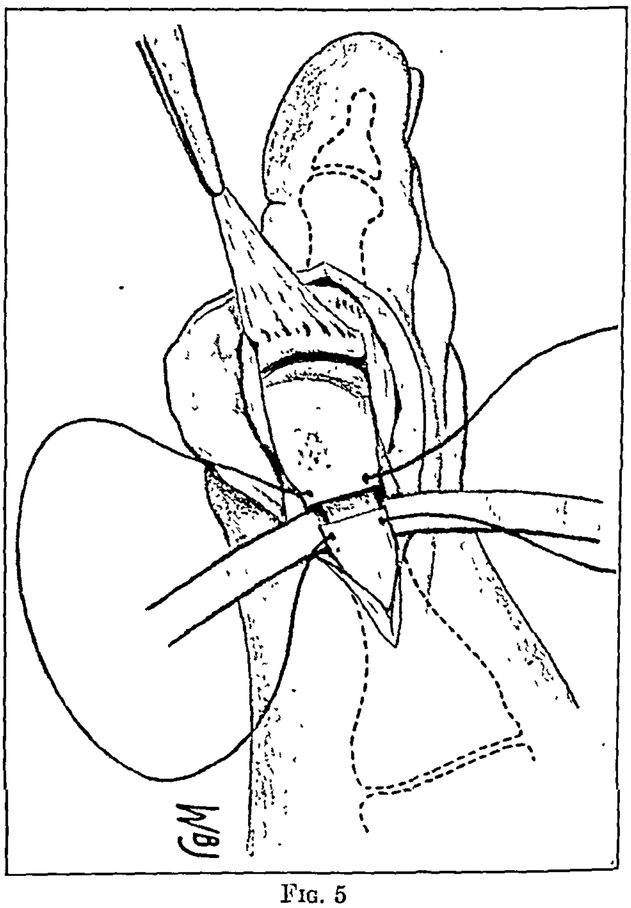

Fig. 5

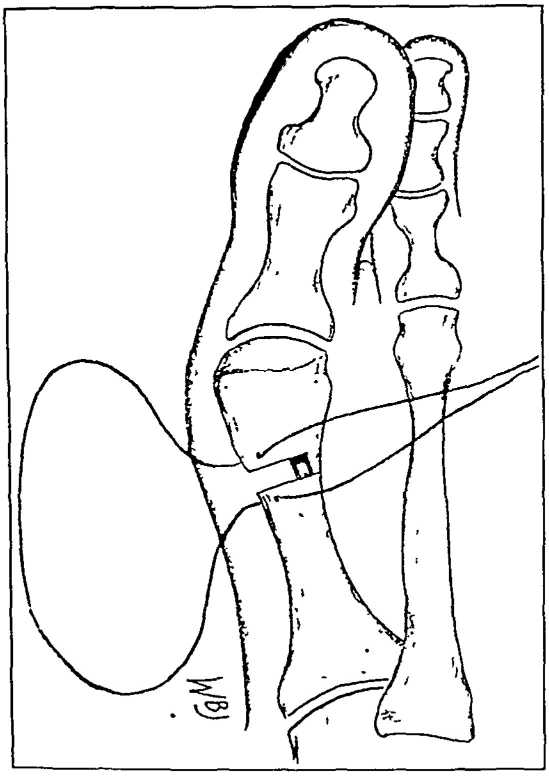

FIG. 6

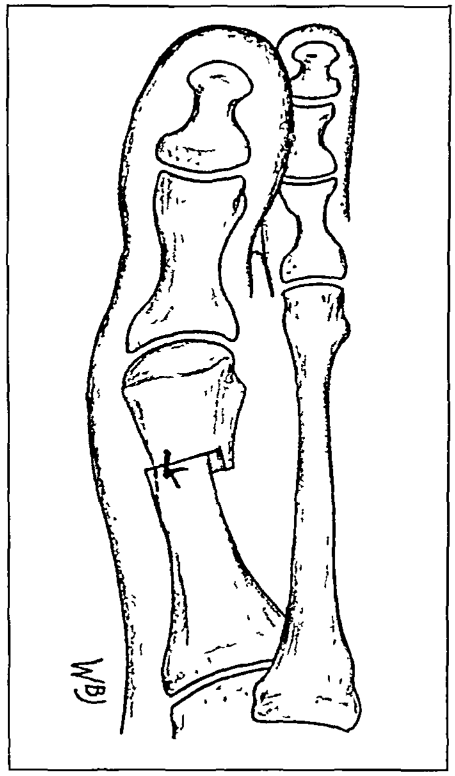

FIG. 7

OPERATIVE TECHNIQUE

1. Two routine orthopaedic preparations are required during the twelve hours preceding operation. The feet are again prepared with a suitable antiseptic in the operating room.

2. An Esmarch tourniquet is applied to the lower leg, extending to approximately four inches below the head of the fibula, thereby avoiding injury to the common peroneal nerve.

3. The feet are draped separately, thus enabling two surgical teams to operate simultaneously.

4. A curved skin incision, five to six centimeters in length, is made over the medial aspect of the first metatarsophalangeal joint with the maximum convexity over the joint itself (Fig. 2). This is followed by subcutaneous dissection and reflection of the skin flaps. The bursa may or may not be excised, depending upon the degree of irritative change.

5. A Y-shaped incision is then made through the capsule and periosteum of the metatarsal shaft (Fig. 3). This flap is freed from the shaft, leaving the base attached to the proximal phalanx. The joint and exostosis are then exposed.

6. The exostosis is excised cleanly, flush with the shaft (Fig. 4).

7. Drill holes are placed through the metatarsal shaft in the anteroposterior plane near the medial cortex, about one-half inch apart, the distal perforation being approximately one-half inch proximal to the articular cartilage (Fig. 5). Number 3 chromic suture is then threaded through the drill holes.

8. The metatarsal shaft is then doubly osteotomized perpendicular to the shaft with the power saw (Fig. 6). The interposing fragment, which should not exceed one-eighth of an inch in breadth, is then removed. The proximal osteotomy is completed with saw or bone-cutting forceps, leaving a short spur on the distal fragment. The depth to which the double osteotomy is carried is determined by the degree of metatarsus primus varus

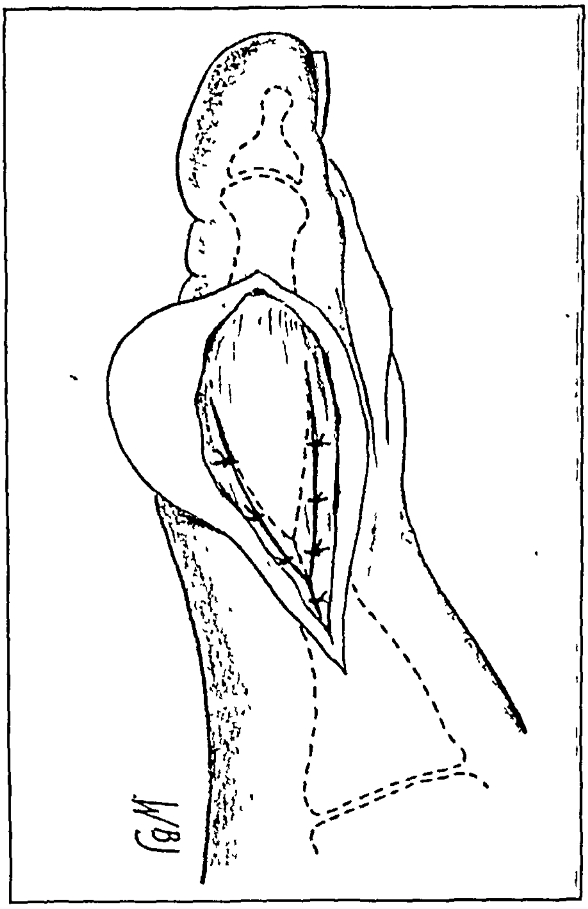

FIG. 8

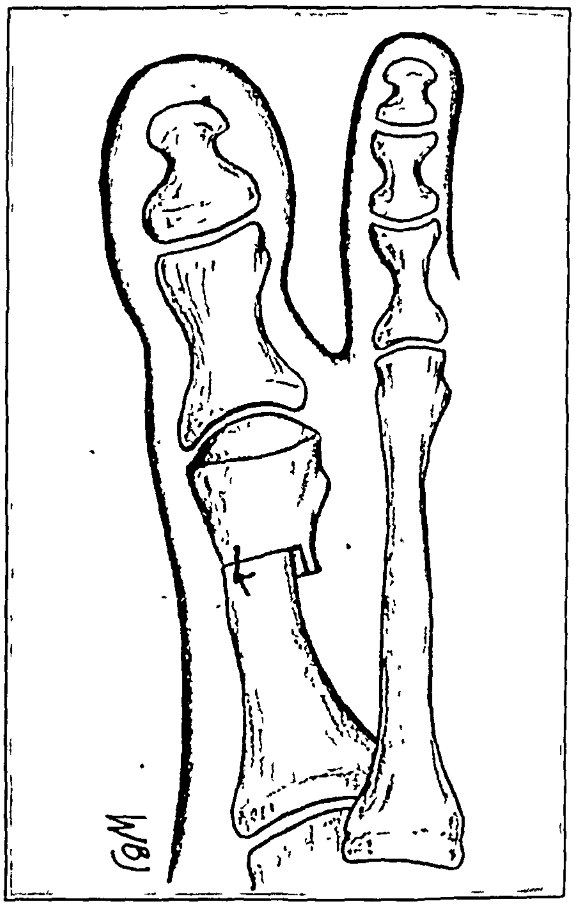

FIG. 9

and the breadth of the foot. In extreme deformities, the grooves penetrate to a depth of approximately one-half the width of the shaft; consequently, upon completion of the proximal osteotomy, a broad spur is left continuous with the distal fragment.

Conversely, if the foot is narrow or the deformity relatively slight, the osteotomy grooves penetrate to the opposite cortex, or approximately five-sixths the width of the shaft. This leaves a narrow spur attached to the distal fragment.

9. The capital fragment is displaced laterally on the proximal, the displacement being maintained by the spur (Fig. 7). The heavy suture is then securely tied, holding the fragments in firm apposition.

10. The great toe is then forcibly abducted and held in slight flexion while a plastic repair is performed on the capsuloperiosteal flap (Figs. 8 and 9). The V-shaped flap is sutured far proximally on the metatarsal shaft to maintain the toe in the overcorrected position. This is followed by the usual closure of the subcutaneous and cutaneous tissues.

Tongue blades are employed as splints on the medial and plantar surfaces, incorporated in the sterile dressing, and secured in place with strips of adhesive. The importance of postoperative care must not be underestimated, and one must be cognizant at all times that there has been a surgical fracture of the metatarsal shaft. We make no effort to disturb the dressing until ten postoperative days have passed, and then only to remove the sutures. Splints are firmly reapplied weekly until five weeks have passed, at which time the patient is ready to wear a straight-last oxford. At this stage, toe posts (Fig. 10) are supplied, which are worn as night splints to prevent direct pressure upon the toes from the bed clothing during this early period. These are worn during the next twelve weeks.

Recently weight-bearing has been permitted four or five days after operation, the patient being encouraged to bear weight on the heels with the aid of crutches. No untoward effects have been noted.

Through close adherence to the technique described, it is possible to correct, both anatomically and mechanically, a painful and disconcerting deformity. The toe is again in alignment with the shaft of the metatarsal which is straightened for the first time. Consequently the foot is somewhat narrower. Normal weight-bearing lines are established, and the patient is again able to walk in the normal heel-toe manner. The sesamoid-metatarsal relationship is not disturbed, nor has the articular cartilage been destroyed. The joint is again made painless through the removal of the exostosis underlying the subcutaneous bursa, which is excised if irritative changes are present.

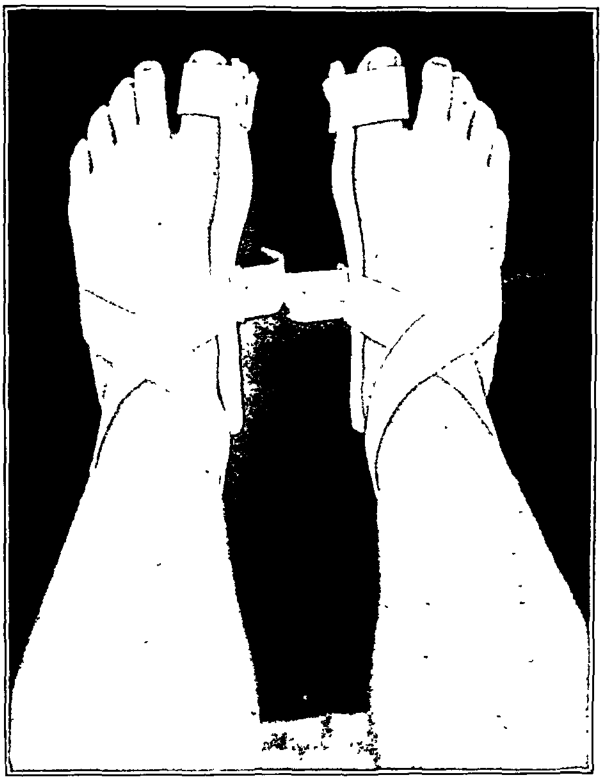

Fig. 10

There is no possibility of aseptic necrosis of the capital fragments, since only the medial portion of the capsule is incised, thereby preserving adequate vascularity. By performing the osteotomy through the shaft rather than through the cancellous bone of the metatarsal head, surgical trauma to the capital fragment is minimized.

In a recent survey of end-results of bunionectomies performed during the past twenty years, questionnaires were sent to all patients regardless of the type of operation. Prior to January 1944, 188 corrections had been accomplished by metatarsal osteotomy. Since that date twenty-three operations of this type have been performed.

In sixty-four cases where varus deviation of the first metatarsal was not great enough to warrant the more radical procedure, the Silver operation was employed. During the same period, six Mayo and four Keller operations were performed. The average period of postoperative observation was four and one-tenth years. Of all patients, 88.3 per cent. were females, and 11.7 per cent. were males. Ages ranged from fourteen to seventy-seven years, the average age being forty-two years.

The following statistics were compiled from the responses of all patients upon whom the metatarsal osteotomy had been performed prior to January 1944.

The questions and responses are as follows:

1. *Are you satisfied with the results?*

One hundred eighty-two patients (96.8 per cent.) were satisfied.

Four patients (2.1 per cent.) noted some improvement, but were not entirely satisfied. (All of these patients had chronic rheumatoid arthritis.)

Two patients (1.1 per cent.) were dissatisfied. (These patients had subacute rheumatoid arthritis and roentgenographic evidence of gout.)

2. *Has there been a recurrence of the previous deformity?*

One hundred sixty-three patients (86.8 per cent.) had not noticed any recurrence of the deformity.

Eighteen patients (9.6 per cent.) noted slight recurrence of the deformity.

Seven patients (3.6 per cent.) noted marked recurrence of the deformity. (All of these patients were arthritics.)

3. *Is there persistent pain over the great-toe joint?*

One hundred eighty-two patients (96.8 per cent.) were completely relieved of pain over the first metatarsophalangeal joint.

Six patients (3.2 per cent.) had persistent pain over the first metatarsophalangeal joint, ranging from slight to severe.

4. *Is there pain over the weight-bearing surface (metatarsals) of the forefoot?*
5. *Did you have pain over the weight-bearing surface of the forefoot (metatarsals) in addition to the bunion before operation?*

From the responses to Questions 4 and 5, we were able to determine that 45.6 per cent. of all patients had some degree of metatarsal pain previous to operation.

Of this group, 60.9 per cent. were relieved completely of discomfort in the metatarsal arch, while 39.1 per cent. noted no change.

Of those who had no metatarsal symptoms before operation, 13.3 per cent. developed pain in the metatarsal arch during the years following.

The other 41.1 per cent. had no metatarsal symptoms, either before or after operation.

These statistics seemed to confirm our clinical impressions and were in general very gratifying. It was somewhat disappointing on the other hand to note that 13.3 per cent. of the patients had developed symptoms referable to the metatarsal arch. This is best explained (1) by the normal aging process with associated vascular changes; and (2) by removal of an excessively wide segment of a congenitally short metatarsal shaft. This technical error has recently been recognized. As a result, the shortened first metatarsal then passively shifts the burden of weight-bearing to the heads of the second and third metatarsals.

It is also to be noted that this type of operation is not particularly successful in arthritics. Our only poor results were encountered in this group of patients. However, reconstructive orthopaedic surgery is in general very discouraging in cases of articular degeneration. It is possible that the Mayo bunionectomy would give better results in arthritics. Our experience with this procedure is not adequate to warrant an opinion.

CONCLUSIONS

In all severe hallux valgus deformities there is a basic metatarsus primus varus which varied from 9 to 13 degrees (in our series). Transverse metatarsal osteotomy is performed to overcome the varus deviation of the first metatarsal. Correction of the hallux valgus is accomplished by plastic repair of the capsuloperiosteal flap. Failure to correct the congenital metatarsal deformity predisposes to recurrence of the "bunion". Excessive shortening of the metatarsal shaft is occasionally responsible for postoperative symptoms of the metatarsal arch. The operation is adaptable to all degrees of deformity. The technique is relatively simple, and the results are uniformly good.

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HEALING TIME IN FRACTURES OF THE SHAFTS OF THE TIBIA AND FEMUR *

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The healing time of the long bones of the lower extremity is notoriously uncertain in adults. It is of particular importance economically to the patient, the family, and the community. As long as weight-bearing is not possible, or is limited, the patient is a liability to himself and his community. Therefore, he is entitled to know, as accurately as possible, how long he will be incapacitated by his fracture. Reasonably accurate prognosis is of great importance in the teaching of students, and in advising the patient, and the insurance company in case of industrial accident. The estimate should, of course, be based on the factors which influence healing,—such as (1) the amount of contusion, comminution, and compounding, (2) the type of fracture, (3) the site of the fracture, (4) the age of the patient, and (5) the method of treatment.

Textbooks by Key and Conwell, Caldwell, Scudder, Lewin, Böhler, Magnuson, Compere and Banks, and Kellogg Speed are at variance on this subject, and tend to underestimate the approximate time of healing. The belief that such fractures do not heal as rapidly today as formerly, as suggested by McMurray, is unfounded, as demonstrated by Watson-Jones and Coltart, and by Young and Blaisdell.

The authors agree with these investigators that distraction, infection, angulation, and disturbance of blood supply (which includes remanipulation) are the most important adverse factors in non-union and delayed union.

Age

In our series of 256 cases there has been no case of non-union in children under fifteen years of age, with the exception of congenital fracture of the tibia. One case of delayed union was encountered in a compound fracture with severe comminution. Youth is an assuring element in the healing of fractures. There are few factors which can prevent the union of any bone in children. There may be malunion with overriding or angulation, but, unless there is interposition of tissue or complicating pathological changes, non-union does not exist. For this reason, all patients under fifteen years of age are eliminated from these statistics of healing time. There seems to be no great difference in the percentage of delayed union or non-union in patients beyond the growing period, whether the fracture be in a person twenty-one or ninety-one years of age.

Blood Supply

Variation in the healing time occurs in all types of fractures, but the variation in healing of fractures of cancellous bone is so much less than in fractures of cortical bone that one may well assume that blood supply is the most important factor of all elements influencing healing. This is further substantiated by experience with fractures of the neck of the femur. Fractures of the femoral shaft rarely go on to non-union, although they are often prone to delayed union. One patient, showing non-union at the end of two years and refusing further treatment, returned at the end of five years with complete union, but with the characteristic deformity of outward bowing of the thigh and inward rotation of the lower fragment. The factor of blood supply is especially important in fractures situated where there is little surrounding vascular tissue, and consequently limited blood supply. This situation is found in the lower half of the tibia, and in this region there is a large percentage of delayed union and non-union.

* Read at the Annual Meeting of The American Orthopaedic Association, Hot Springs, Virginia, June 1, 1944.

TABLE I

FRACTURES OF THE TIBIA AND FIBULA

Group	Average Healing Time: For All Cases* — No. of Cases	For All Cases* — Clinical Union (*Weeks*)	For All Cases* — Union Shown by X-Ray (*Weeks*)	In the Third of the Cases First to Unite — Clinical Union (*Weeks*)	In the Third of the Cases First to Unite — Union Shown by X-Ray (*Weeks*)	In the Third of the Cases Last to Unite — Clinical Union (*Weeks*)	In the Third of the Cases Last to Unite — Union Shown by X-Ray (*Weeks*)	Cases Uniting in Less than 24 Weeks — Authors' Series (*Per Cent.*)	Cases Uniting in Less than 24 Weeks — Series of Watson-Jones and Coltart (*Per Cent.*)
1. Reduction: continuous plaster fixation	46	12	21	8.5	13	16	24	78	95
2. Reduction by traction, later plaster fixation	40	19	29	10.0	16	25	25	50	74
3. Distraction or other separation of fragments	3	16	26	—	—	—	—	33	31
4. Compound, not infected	10	18	24	7.0	13	23	26	70	72
5. Infected, all causes	11	26	40	—	—	—	—	27	35
All groups	110	18	28						

* The average hospital stay for all patients with fracture of the tibia and fibula was twelve days.

TABLE II

AVERAGE HEALING TIME IN REGARD TO LOCATION OF TIBIAL FRACTURE

Location	No. of Cases	Clinical Union	Union Shown by X-Ray
Lower third	39	16 weeks	25 weeks
Junction of middle and lower thirds	16	19 weeks	29 weeks
Middle third	39	18 weeks	29 weeks
Junction of upper and middle thirds	2	15 weeks	29 weeks
Upper third	14	14 weeks	18 weeks

TABLE III

AVERAGE HEALING TIME FOR DIFFERENT TYPES OF FRACTURES OF THE TIBIA AND FIBULA

Type of Fracture	No. of Cases	Clinical Union (*Weeks*)	Union Shown by X-Ray (*Weeks*)
Transverse	8	14	21.0
Oblique	28	16	22.0
Spiral	14	12	19.5
Comminuted	60	19	30.0
Compound	32	23	34.0

METHOD OF TREATMENT

In view of the experience with our own cases and with those patients who have come to us from elsewhere, we feel that nature will do a great deal, if given a reasonable chance by the preservation of length and alignment, and by the restoration of function. The outcome will be better with conservative methods, as far as the healing time, the comfort of the patient, and the end result are concerned; certainly the chance of complication is much less. There are serious dangers in radical treatment, but one must admit the necessity and advantage of certain forms of internal fixation in selected cases. Undoubtedly there are many patients who have suffered the effects of radical treatment in inexperienced hands. The authors believe in the use of internal and external skeletal fixation of fractures as an unavoidable necessity in certain cases, rather than as a routine method of choice. Its use in no way speeds the time of union of the fracture, and often delays it. Skeletal fixation is necessary when it is impossible to hold the fragments in position in any other way; its employment usually means quicker evacuation of the patient from the hospital. However, in all cases, continued and, if necessary, prolonged immobilization is urged; and early weight-bearing, regardless of mechanical fixation, should be discouraged. It should be noted that our observations are not based upon our own experience with respect to skeletal fixation, but upon the results noted by us in referred cases treated by others.

RESULTS

The series of cases considered and tabulated here includes 149 consecutive cases of fracture of the tibia and fibula, and 107 cases of fracture of the femoral shaft. They were practically all among civilians, rather than war injuries.

Twenty-five cases of fracture of the tibia and fibula have been eliminated, because the patients were under fifteen years of age; the average age was nine and a half years, and the average healing time was seven and a half weeks. Thirty-six cases of fracture of the shaft of the femur have also been eliminated, because the patients were under fifteen years of age; the average age of this group was six years, and the average clinical healing time was four weeks. The average time of healing, as shown by roentgenogram, for all groups was nine weeks.

Fourteen adult patients were eliminated from each group because of (1) failure to return for final observation, (2) amputation, or (3) death resulting from fracture or other complications. There remain for further analysis 110 cases of fracture of the tibia and fibula, the average age of these patients being forty-one years, and fifty-seven cases of fracture of the shaft of the femur, the average age of the patients being forty-two years.

Clinical healing was determined by the lack of any evidence of mobility on manipulation and by the presence of palpable callus about the site of the fracture. Roentgenographic evidence of union was determined by the presence of complete connective callus between the ends of the fragments.

The grouping used in this analysis is that employed by Watson-Jones and Coltart.

Group 1. Those cases in which immobilization was continuous. Casts were removed intermittently only for roentgenographic interpretation of progress.

Group 2. Cases where traction was used as a primary measure and plaster casts were later applied.

Group 3. In these cases, traction or manipulation led to the separation of the fragments to the extent of one-eighth to three-eighths of an inch.

Group 4. Compound fractures, either of the minor or major types, without infection.

Group 5. Definitely infected fractures (which included those reaching treatment after the safety period), those secondary to débridement, and those having delayed infection.

TABLE IV

FRACTURES OF THE SHAFT OF THE FEMUR

Group	Average Healing Time								
	For All Cases			In the Third of the Cases First to Unite		In the Third of the Cases Last to Unite		Cases Uniting in Less than 24 Weeks	
	No. of Cases	Clinical Union (*Weeks*)	Union Shown by X-Ray (*Weeks*)	Clinical Union (*Weeks*)	Union Shown by X-Ray (*Weeks*)	Clinical Union (*Weeks*)	Union Shown by X-Ray (*Weeks*)	Authors' Series (*Per Cent.*)	Series of Watson-Jones and Coltart (*Per Cent.*)
1. Reduction: continuous plaster fixation	39	9.5	20	6	13	13	25	75.0	95
2. Reduction by traction, later plaster fixation	9	8.0	20	6	13	10	25	63.5	64
3. Distraction or other separation of fragments	2	9.5	31	—	—	—	—	—	—
4. Compound, not infected	1	18.0	44	—	—	—	—	—	—
5. Infected, all causes	3	11.0	37	—	—	—	—	—	—
All groups	54 *	11.2	30.4						

* Not including two cases of non-union and one that did not heal for 148 weeks.

TABLE V

AVERAGE HEALING TIME IN REGARD TO LOCATION OF FEMORAL FRACTURE

Location	No. of Cases	Union Shown by X-Ray
Lower third	14	18 weeks
Middle third	24	21 weeks
Upper third	16	25 weeks

TABLE VI

AVERAGE HEALING TIME FOR DIFFERENT TYPES OF FRACTURES OF THE SHAFT OF THE FEMUR

Type of Fracture	No. of Cases	Union Shown by X-Ray (*Weeks*)
Transverse	13 (1 non-union)	19.0
Oblique	15	23.5
Spiral	1 (non-union)	—
Comminuted	26	22.5
Compound	6	23.5

Fractures of the Tibia and Fibula

The results obtained in fractures of the tibia and fibula are shown in Table I, which includes a comparison of our results with those of Watson-Jones and Coltart.

The healing time, in relation to the location in the tibia, is shown in Table II.

Whether the fracture was comminuted, transverse, oblique, spiral, or compound seemed to make very little difference in healing time, although the comminuted and compound fractures averaged a little longer (Table III).

Fractures of the Shaft of the Femur

The results obtained in fractures of the shaft of the femur are shown in Table IV.

Internal fixation was not used in any of our cases. Pin and bar fixation was used in only one. Russell traction was the most effective means of obtaining a good result, and it was used in all cases where manipulative reduction could not be accomplished. Its drawbacks are the time and patience required, and its necessities are plenty of good moleskin adhesive and constant watching. Many poor results can be obtained by any method, if doctor and patient forget these elements or compromise upon them. The callus may be too little, and the time not late enough.

The average hospital stay for patients with fracture of the femur was fifty-four days. The average stay for forty-six adults in traction was seventy-three days. The average stay for eight patients in skeletal traction was sixty-eight days. (For thirty-three children in traction, the average stay in the hospital was forty and six-tenths days. Two children in skeletal traction remained an average of fifty-six days.)

Fractures of the lower third of the shaft of the femur seemed to heal more rapidly than those in the middle and upper thirds. The upper third was the slowest to heal and the most difficult to manage, in spite of the fact that it was never possible to create distraction in this area (Table V).

In Table VI an analysis is made of the time element in healing of fractures of the femur in relation to their anatomical and physical types. Transverse, oblique, spiral, comminuted, and compound fractures are considered.

CONCLUSIONS

1. The long bones of the lower extremity are the biggest and strongest bones in the body. The force required to break them must necessarily be great, and the damage taking place at the time of injury is not only in the bone, but in the surrounding tissues. The speed of healing of fractures is usually proportionate to the amount of available circulation to and between the fragments.
2. In spite of the foregoing deduction, all the causes of delayed union and of non-union have not yet been determined.
3. The percentage of delayed union and non-union in fractures of the femur is not so great as in fractures of the tibia.
4. There are more cases of delayed union and non-union in the middle third of the tibia than in the upper and lower thirds.
5. The majority of our patients received some form of calcium therapy during their fracture treatment, with little recognizable effect on the end result.
6. In the instructions to patients and students, due consideration should be given to the slowness and uncertainty of the healing of fractures of the tibia and femur, so that patients may be prepared for the long period of time possibly necessary for the healing of these fractures.
7. The use of skeletal traction and the use of internal or external skeletal fixation in no way speeds the healing time of bone, and in some instances retards it, because of distraction, infection, or the osteolytic effect of the metals used.
8. In the series of cases here presented, circumstances in some instances necessitated

the use of skeletal traction, plating, and external fixation (Haynes). In none did we feel that the results obtained by such methods were in any way superior to those of conservative treatment, when alignment could be maintained even at the expense of a loss of length of as much as three-quarters of an inch.

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ECHINOCOCCOSIS OF BONE

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HISTORY

Echinococcus disease is mentioned in the Talmud, and was known to the early Jews through their sacrificial slaughter of animals. Hippocrates, Aretaeus, Galen, Rhazes, and several physicians of the seventeenth century refer to it. Redi, in the latter period, demonstrated its animal origin, and Goeze, in 1782, accurately described the cysts and the tapeworm heads. Von Siebold (1852) infected dogs from hydatid cysts, and proved the relationship between the larva and the adult taenia. Leuckart, in 1876, described the complete life history and morphology of the parasite. Dévé, in 1901 and subsequently, through his experimental, clinical, and pathological studies of the disease and the parasite, added greatly to our knowledge. He produced the disease in the rabbit by direct inoculation. Dew, in his book (1928) and various articles, has given a very thorough account of the disease, and of its occurrence in Australia.

The North American literature begins with the report of Osler, who, in 1882, reviewed sixty-one American cases, one-third of them of foreign origin. He was unable to find the taenia echinococcus in dogs, but found it in cats, and one of his students found it in ten of 270 hogs examined. He pointed out the relation of echinococcus disease to drinking water. Sommer, in 1896, reviewed the hundred cases to that date. Lyon, in 1902, gave a third statistical study of the disease, listing 241 cases, 135 of which were his own, the origin of the patients, and the sources of the disease. Riley, in 1933, discussed the reservoirs of echinococcosis in Minnesota, and mentioned the finding of echinococcus cysts in six out of thirteen moose examined. Magath, in 1937, in a discussion of the disease in the United States and Canada, found a total of 482 reported cases, most of them in foreign-born patients who had acquired the disease before coming to this continent, and added ten cases diagnosed at the Mayo Clinic. He reported nineteen cases of United States origin, and three of Canadian, the first case being found in 1900 in each country.

BONE INVOLVEMENT

According to Gangolphe, bone involvement with echinococcosis was first mentioned by van Wy in 1786, then by van der Haar, in 1800, followed by Cullerier, in 1806, and by Chaussier in 1807. Webster, in 1819, reported from London a case of tibial involvement. Keate, in 1819, reported the disease in the frontal bone of a girl of eighteen, whom he operated upon twice, and who recovered. Other early bone cases were reported by Barckhausen (in 1819), Wickham (in 1827), Ollivier, D'Angers, Cooper, Dupuytren, Bérard (in 1851), Albanese, and Küster.

There are numerous cases of echinococcus disease of bone in the world literature, largely individual case reports. Réczey, in 1877, listed thirty-three bone cases. Gangolphe, in 1886, reviewed fifty-two cases and wrote an interesting monograph. Bauer, in 1913, summarized the 243 cases previously collected by Gangolphe, Titoff, and Reich; and Pasquali, in 1930, collected 406 additional cases. Greenway, in 1922, reported nine bone cases from Argentina; Pessano, in 1933, twenty-eight cases from that country; and Toole, in 1930, nine cases from Greece. Desplas, Boppe, and Bertrand, in 1924, tabulated forty-three pelvic bone cases; and, in the same year, Costantini reviewed fifty-three cases. Kienböch, in 1933, collected eighty-six cases and included them in an interesting monograph. Grisel and Dévé, in 1929, listed 190 spine cases. There is considerable overlapping of cases in the various summaries, and the diagnosis was not fully established in

all of the cases, but it seems safe to say that up to the present time there may be approximately 1,000 cases of echinococcosis of bone reported in the world literature.

The first case of bone involvement in North America was reported by Woods in 189 (humerus), and it was included in the review by Lyon in 1902. Walker and Cummins, in 1917, reviewed eighty-eight cases of bone involvement in the world literature and added a second North American case (tibia). The third was reported by Hines in 1926 (vertebrae), the fourth by Stone in 1930 (pelvis), and two additional pelvic bone cases by Coley in 1932. The author, in 1932 and 1938, presented at the New York Academy of Medicine the seventh case (femur), which is more fully reported herewith. Sinberg, in 1936, reported the eighth North American case (sternum); in the Case Records of the Massachusetts General Hospital, in 1939, the ninth was reported; and Hood, Lambert and Thomas reported the tenth (pelvis). The case reported herewith is unusual because it is one of the ten North American cases, the first with femoral involvement, and the only *known instance in which the cavity was filled with bone chips after removal of the cyst*

ETIOLOGY AND DISTRIBUTION

Echinococcus disease is endemic in every continent of the world, and is especially common in Australia, New Zealand, South America, Siberia, North Africa, Asia Minor the Balkans, and Iceland. Its prevalence bears a very close relationship to the proportion of sheep to the local population, and to the frequency with which dogs eat the viscera of sheep. The dog is the chief definitive host for the taenia, but it has also been found in some of our wild animals (wolf and jackal). The intermediary hosts are sheep, goats hogs, cattle, and moose. The ova are shed in the faeces of the dog, which may be eaten by hogs, or may be deposited on grass eaten by sheep or cattle, or in water drunk by animals or man. The ova may be transmitted directly from the dog to the hands of man (especially little children), and thence to his mouth, particularly when he does not wash before eating. The presence of the disease in man depends upon his putting his hand to his mouth, or upon eating uncooked food, or drinking unboiled water contaminated by dog faeces, and is therefore directly related to and controllable by his sanitary habits. The disease in the dog is dependent upon his eating the infected viscera of sheep or of other animals, and can be controlled by destroying these viscera, or by keeping dogs from them,—that is, by sanitary control of slaughter houses. The Federal Meat Inspection Service, in 1924, found hogs infected in the ratio of one to 2,500, and sheep one to 60,000; but, in 1935, cattle were found to be infected in the ratio of one to 513. The Bureau of Animal Husbandry reported an incidence of 3.2 to 10,000 for cattle and 5 to 10,000 for calves in 1941. These infections probably were obtained through wild animals, as only one authentic case of dog infection has been reported in this country, largely due to the elimination of dogs from slaughter houses. The prevalent "black market", due to the War, may easily result in a reversal of this situation. The present movement of military forces and populations over the face of the earth, and poorer sanitary conditions in certain areas, will certainly result in an increase of the disease, even among our own forces.

The six-hooked echinococcus embryo measures about thirty-five micra and is covered by a chitinous envelope, resistant to exposure. The embryo loses its envelope in the upper intestine of the intermediary host. It bores through the intestinal wall to enter a vein, whence it is carried by the portal vein to the liver. The majority of the embryos remain in the liver, but some of them pass through the liver. Most of these are filtered out in the lungs. A few pass through the vessels of the lungs and lodge finally in the muscles, spleen, kidney, or bone. Thus about 75 per cent. of human lesions are found in the liver, 15 per cent. in the lungs, 2 per cent. each in the kidneys and the spleen, 4 per cent. in muscle, and 1 per cent. in bone.

The embryo provokes a cellular reaction in the tissues,—mononuclear, eosinophilic, and fibroblastic, with occasional giant cells. The embryo develops rapidly (in about

three weeks) into the larva, a cyst containing hydatid fluid and surrounded by a laminated wall, the result of intracystic pressure. The wall prevents the leakage of the specific fluid which excites the reaction in the host tissues, whereupon the reaction ceases, and the host tolerates the parasite. The wall consists of an outer laminated hyaline membrane, and an inner germinal layer, which lodges the brood capsules, filled with scolices. The fluid is a buffer, and is the source of nutrition for the scolices. It contains sodium chloride (0.6 to 0.8 per cent.) and a small amount of coagulable protein (albumin). There are usually thousands of brood capsules in a single cyst, white opaque granules just visible to the naked eye. The buds in the capsules develop into the scolices, with suckers, hooklets, and contractile tissue. There may be daughter cysts inside the mother cysts.

The dog is infected by eating the viscera of the sheep, pig, or cattle. The ingested scolex develops in the intestine of the dog into the mature cestode, a worm three to six millimeters in length, with three or four segments. One dog may harbor thousands of worms. The terminal segment houses the uterus, in which 500 to 800 ova soon develop. These mature segments are discharged in the faeces of the dog, and the life cycle of the parasite is thus continued.

DIAGNOSIS

The symptoms of echinococcus disease in man depend upon the size and location of the cyst, or, more often, upon leakage or rupture of its contents. Pressure symptoms are uncommon in the liver, lungs, kidneys, spleen, or bone. A cyst of a skeletal muscle is likely to be disturbing cosmetically rather than otherwise. Leakage from the cyst usually causes sudden and often serious symptoms. There may be an immediate anaphylactic reaction, or the disease may spread directly into neighboring tissues, especially body cavities such as the peritoneum, or in the blood and lymph streams to a more distant organ. Rupture of the cyst sometimes results in its death, especially if the rupture is external and complicated by infection. Inflammatory symptoms follow infection. Anaphylaxis is due to absorption of the specific hydatid protein in a previously sensitized patient, and may cause dyspnoea, cough, cyanosis, cardiac anxiety, fever, urticaria, pruritus, vomiting, pulmonary oedema, and even delirium.

Bone involvement occurs in about 1 per cent. of cases of echinococcus disease. The larger series of cases reported show that the pelvis is involved in about 36 per cent., the spine in 18 per cent., the sacrum in 11 per cent., the femur in 17 per cent., the tibia in 9 per cent., and the humerus in 10 per cent. Pain is the most common symptom of bone involvement, and is due to leakage or to pathological fracture. Rupture or pathological fracture may be followed by infection, with pain, swelling, redness, and tenderness; however, a mass may be noticed before the onset of pain. The mass is rounded but somewhat irregular, usually firm or hard, but sometimes semifluctuant, not tender unless infected, and attached deeply and firmly to the bone. Motion may be limited and painful, if the mass is near a joint. The inflammatory signs are present, if the cyst is infected and near the surface. The signs of fracture, bony deformity, false motion, crepitus, and disability, may be present with this complication. A vertebral lesion may cause pressure upon the spinal cord or cauda equina, with spastic or flaccid paralysis, while the spinal fluid below the lesion may have a high protein content, and there may be a partial or complete block.

LABORATORY FINDINGS

The laboratory may be of considerable help in confirming the diagnosis. Scolices, hooklets, or fragments of laminated membrane may be found in the sputum, urine, or faeces after rupture of a cyst. Three immunological tests, dependent upon antibody reaction, are usually positive if properly done, unless the cyst has remained completely sealed, or is dead. The intradermal test of Casoni is positive in about 95 per cent. of cases. This test was further developed by Dew, Kellaway, and Williams.

A more convenient test is that of Culbertson and Rose, utilizing the antigen of a related cestode, dipylidium caninum. Neither test is specific for the particular type of cestode.

The complement-fixation test (Ghedini; Weinberg; Fairley), with fresh hydatid fluid from sterile sheep cysts, is positive in about 90 per cent. of cases, depending upon whether the cyst is ruptured or infected within the previous two months. It will be negative within one year after complete eradication of the disease. The precipitin test, done with the cyst fluid of the sheep, is less dependable (Fleig and Lisbonne; Sachs-Georgi; Bryce, Kellaway, and Williams). Eosinophilia of 20 to 50 per cent. is common, depending upon leakage of the cyst contents.

Aspiration or puncture of the cyst yields the characteristic fluid, and often scolices or fragments of laminated membrane, but should not be practised because of the dangers of sensitizing the patient, of anaphylaxis if he is already sensitive, or of producing secondary cysts by implantation of the scolices which escape into the tissues. The fluid is clear and limpid, or milky, unless stained by other fluids. The scolices are white granules, just visible to the eye. Daughter cysts are milky white, opalescent, semitransparent, and hollow.

ROENTGENOGRAPHIC FEATURES

The roentgenogram may be of great value in demonstrating the presence and location of the lesion, but may not indicate its nature.[3,39] The cyst is somewhat radiopaque (of muscle density), because of its saline content, and will be seen readily in the lung fields, but it may not be distinguished in the abdomen. The bone lesions are polycystic, with fairly sharp margins, but without productive reaction or regional or subperiosteal decalcification unless infected. They must be distinguished from giant-cell tumor, the cystic type of tuberculosis of long bones, malignant tumor, osteomyelitis, and osteitis fibrosa cystica. The surrounding bone is thinned and may be even expanded or ruptured by the pressure of the lesion. Arterial occlusion results in necrosis, and small sequestra may be seen. Fracture through the involved area is not infrequent, and non-union often results.

DIFFERENTIAL DIAGNOSIS

Thus the differential diagnosis depends largely upon the possibility of echinococcus disease, upon the laboratory tests, and upon the roentgenographic appearance. A negative Mantoux test will rule out tuberculosis. Calcium, phosphorus, and phosphatase determinations may help in distinguishing osteitis fibrosa cystica, or Paget's disease. The white blood count, the erythrocyte sedimentation rate, and the temperature distinguish osteomyelitis (except cysts with secondary infection). The slow, silent course is indicative of echinococcosis rather than of malignancy.

TREATMENT

The treatment of echinococcosis of bone is unsatisfactory. No drug has been found which will safely kill the parasite, by any method of administration. Roentgenotherapy has probably never destroyed the parasite. Excision of the cyst, with or without exteriorization (marsupialization), has been the most successful treatment. Removal of the cyst carries the risks of anaphylaxis and of implantation at the time of operation. If the patient is already sensitive, leakage of fluid at the time of operation may result in an anaphylactic reaction. If he is not sensitive, he may be made so; and if there is another cyst in his body or a recurrence, the danger of anaphylactic reaction persists. Recurrence may be due to incomplete removal of the cysts, or new cysts may develop from implantation at the time of operation.

A technique has been devised by Dévé for sterilization of the cyst immediately be-

fore operation to prevent implantation or recurrence. The cyst is packed off, aspirated, and injected with 2 per cent. formalin in amount equal to the aspirated fluid. After five minutes the formalin is withdrawn and the cyst is excised. (The formalin does not usually sterilize daughter cysts, which must be removed completely to prevent recurrence.) Twenty cubic centimeters of formalin and ten cubic centimeters of acetic acid are mixed with two grams of a solution of potassium ferrocyanide in 970 cubic centimeters of distilled water, and sterilized ten minutes at 105 degrees Fahrenheit. The solution is injected after the aspiration. The method has been further modified to prevent anaphylaxis or recurrence.

Local excision of echinococcus of bone and muscle has often been unsuccessful, either because of incomplete removal, or implantation. Marsupialization has not been practised for involvement of the extremities, although it might be advisable in selected cases. Amputation of the involved extremity has removed the localized disease, when done well above the involved area, and is often the method of choice. Lesions of the spine or pelvis have occasionally been excised with good results, but more often complete excision is impossible. Possibly, in such cases, if the lesion is single, sterilization alone would be sufficient, or marsupialization with instillation of a sulfonamide. Amputation was refused in the case here presented, whereupon local excision was attempted, and bone chips were packed into the cavity.

CASE REPORT

A laborer, born in Southern Italy, emigrated to the United States in 1919. He came to the New York Orthopaedic Hospital in February, 1932. He was then forty years of age. He complained of pain in the right knee of four months' duration. Onset of pain had followed a fall in which his knee had been twisted. At that time, he was taken to an orthopaedic hospital where a roentgenogram was reported negative, and baking was given. The knee had remained swollen, stiff, and painful, requiring him to remain recumbent for two and a half months. An aspiration was done at another orthopaedic hospital three months after the onset, but no roentgenogram was made at that time. When he was admitted to the New York Orthopaedic Hospital, four months after onset, he still complained of swelling, but the

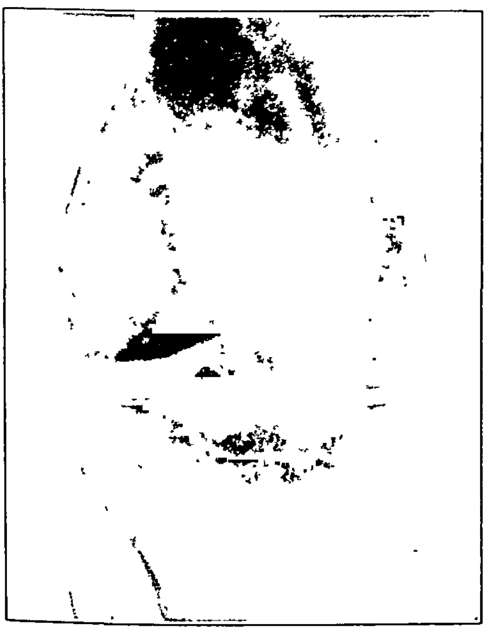

Fig. 1-A

Fig. 1-B

December 18, 1931. Roentgenograms of right knee show large polycystic lesion of lateral femoral condyle with sharp margins, and smaller cysts above intercondylar notch; erosion posterior to notch and possibly at distal lateral margin of lateral condyle; and moderate dense swelling of capsule. No productive or periosteal reaction is apparent.

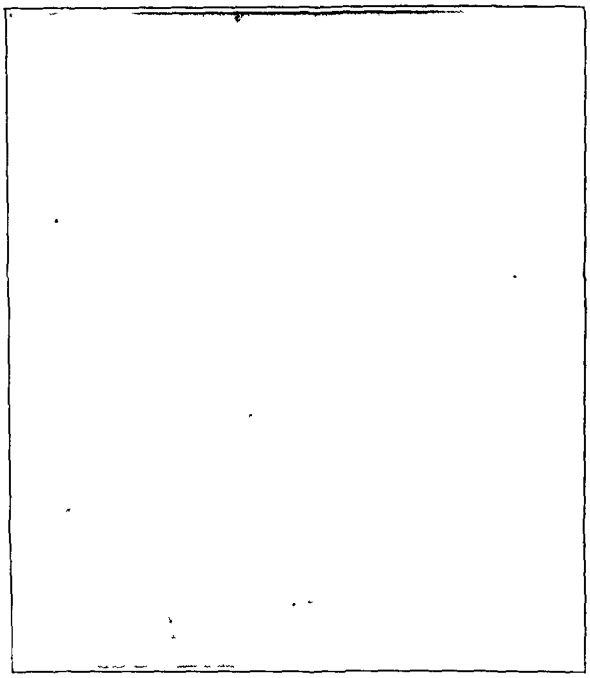

FIG. 2-A

FIG. 2-B

March 18, 1932. Cysts in lateral condyle have been partially removed. There is air in the bone cavity and soft tissues about the lower femur.

pain and stiffness were less marked. He had had no previous trouble with the knee except a "sprain" eight years previously, from which he had fully recovered. He had had no cough and had not lost weight. (It is of interest that two of his small children had been recently treated for tuberculosis of the spine.)

Physical examination was negative, except that the right knee was moderately swollen, because of fluid in the joint. The tissues in the popliteal region and proximal to it were thickened. There was full extension, with flexion to 80 degrees without pain or spasm. Slight tenderness was present about each femoral condyle; the ligaments were slightly relaxed. He had a mild limp.

The Wassermann test was negative; the Mantoux, positive. The leukocyte count was 10,000, with 70 per cent. polymorphonuclear leukocytes, and 1 per cent. eosinophils. The red cell count was normal, and the urine negative. Roentgenographic examination revealed a polylocular cyst of the lower end of the femur with several perforations of the cortex. There was no marginal condensation and no expansion. Roentgenograms of the pelvis, of the spine, of the abdomen, and of the lungs were negative. Giant-cell tumor, chondrosarcoma, and tuberculosis were considered possibilities.

An exploration was performed in March 1932. An incision was made just above the lateral femoral condyle, avoiding the joint. Beneath the fascia of the vastus lateralis a cavity was encountered, containing 200 cubic centimeters of thick, light yellow, highly refractile liquid, resembling semisolid fat. This cavity communicated with the interior of the femoral condyle through a cortical perforation. It was lined with a tough, gray, rugose membrane, one-eighth of an inch thick, and had many subsidiary pockets, formed by sharp-edged crisscrossing bands.

The bony cavity was similar to that seen in the roentgenogram, the shell laterally being very thin. It was filled with ovoid, transparent, gelatinous masses about one-half an inch in diameter. There was a thin, incomplete, yellow-gray lining. Frozen section was reported to show chronic inflammation. The contents of the cavities did not resemble anything any of us had seen before, but suggested the likelihood of an echinococcus cyst.

The cavity in the popliteal region was thoroughly cleaned out, and that in the bone scooped out as well as possible without breaking down the bony partitions. Because of some uncertainty as to the diagnosis, it was considered unwise to do a more extensive procedure at this time. The wound was closed, and healed *per primam*. The postoperative course was uneventful.

Cultures gave no growth. Two guinea pigs were inoculated and eventually killed, but no disease was found. Microscopic examination of the fresh contents of the cyst revealed structureless stratified layers of amorphous material, associated with fatty-acid crystals. Sections of the bone showed a rarefying osteitis with chronic inflammation and foreign-body giant cells. The soft tissues were bounded by granulation tissue with many foreign-body giant cells in the superficial layers. Specimens were seen by Dr. Stewart of Memorial Hospital and Dr. O'Connor of Rockefeller Institute, who made a diagnosis of hydatid cyst.

Amputation was advised, as the possibility of curing the lesion seemed remote, but the patient

refused. Resection of the involved bone seemed hopeless. Accordingly, the cavities were again exposed for a more thorough curettage, and for the insertion of bone chips. The soft-tissue cavity had shrunk to one-third its former size. Both cavities were filled with old blood. No new gelatinous masses had formed, but a number of pockets remained in the bone. These were thoroughly curetted, and the cavity was carefully and completely swabbed with pure phenol, then with alcohol, and was finally curetted again to bare bone. The cavity was filled with medium-sized chips from the tibia, 250 cubic centimeters of bone chips being required. A long leg cast was applied, as the remaining bone was quite thin. The wound healed *per primam*.

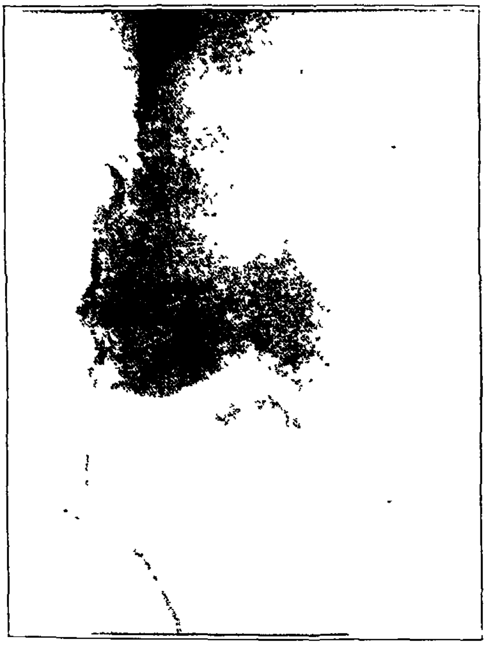

Fig. 3-A

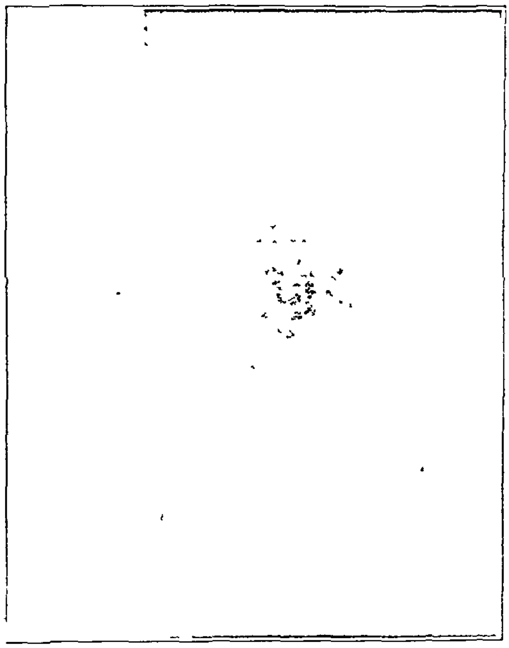

Fig. 3-B

May 4, 1932. Bone cavities have been fully excised and snugly packed with numerous small chips. The air has disappeared.

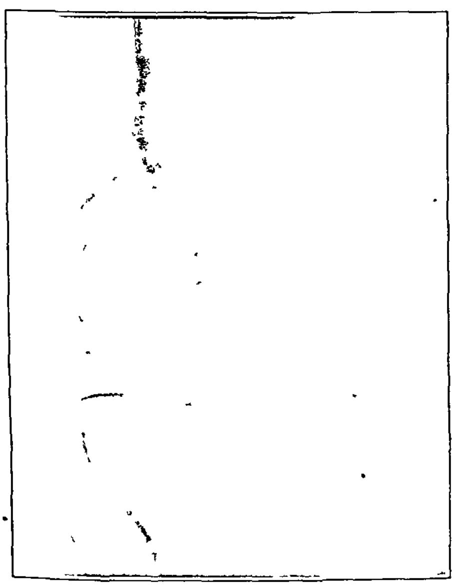

Fig. 4-A

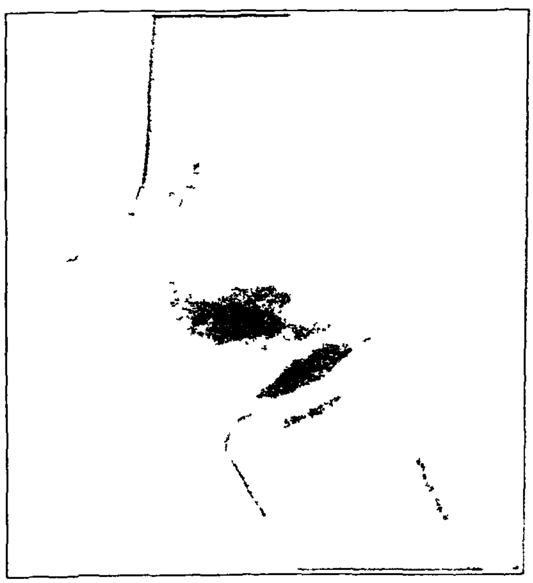

Fig. 4-B

July 28, 1933 Chips have coalesced and cavities have been obliterated, except for several small areas near lateral and distal margins of lateral condyle.

Seven weeks after the operation there was no tenderness, redness, swelling, or joint fluid. The range of flexion was 180 to 115 degrees. There was no induration about the wound, nor was there any popliteal mass. Weight-bearing was begun at this time. Five weeks later, the flexion had increased to 60 degrees. Seven months after the operation, the patient had no pain or fatigue and was active without handicap. He could walk several miles, and had no limp or limitation of motion. There was moderate joint fluid and periarticular thickening, and slight warmth. There was no pain, tenderness, or spasm. Flexion was 180 to 45 degrees. No recurrence of the disease could be seen by roentgenogram. Gradually the chips became more confluent.

One and one-half years after the operation, the swelling of the knee increased, and aspiration yielded fifteen cubic centimeters of glairy, sparkling, yellow fluid. The swelling and thickening persisted, and there was some disability. It appeared definite that the knee joint was involved.

Fig. 5-A

Fig. 5-B

September 17, 1934. Further coalescence of chips is evident.

Fig. 6-A

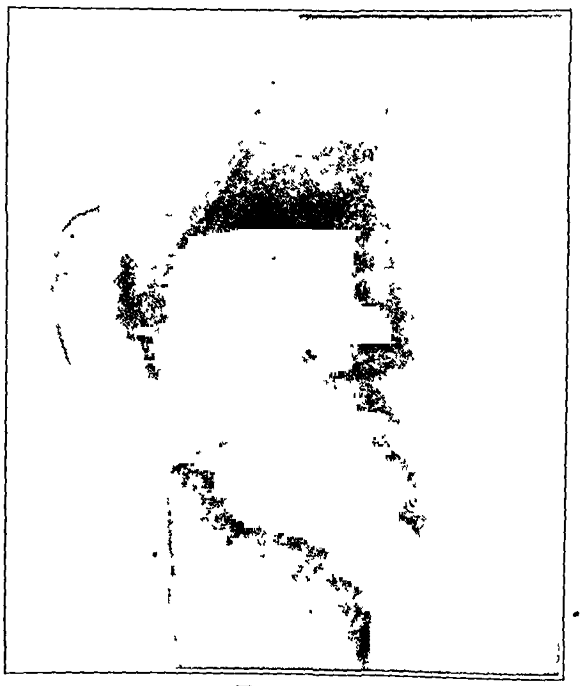

Fig. 6-B

September 17, 1935. Roentgenograms taken before synovectomy show thin joint space and marked, dense swelling of capsule. Lesion in femur is unchanged.

In September 1934, two and a half years after the first operation, the knee joint was explored. One hundred cubic centimeters of cloudy, yellow fluid, with fibrin flakes and masses, were obtained. The synovial membrane was pale red. Villous processes were free in the joint. Extending from the superomedial corner of the suprapatellar pouch, into the middle third of the thigh, was a prolongation of the cavity, with dirty gray walls. The femoral articular cartilage and the medial meniscus were degenerated, but were not involved by the disease. A complete anterior synovectomy was performed, including the menisci. The wound healed *per primam,* and the patient began walking in ten days, with 30 degrees of motion.

Microscopic examination showed a thick synovial membrane, with numerous villi, and a dense fibrous-tissue base with many foci of lymphocytic infiltration. There were many cystlike structures of various sizes. These exhibited walls made up of an outer layer of fibrous connective tissue, an intermediate layer of epithelioid cells and giant cells, and a partially detached inner layer of laminated cellular acidophilic membrane. Some of the cavities contained firmly granular material. Numerous less fully developed tubercle-like structures appeared to be early stages in the evolution of the cyst.

For one year following synovectomy the patient had no pain, little disability, and good motion, but he had moderate relaxation at the knee. Then the swelling increased, the knee became weaker, and his limp became troublesome. Motion was limited to 75 degrees. There was moderate fluid and thickening; the knee was warm, and the veins were swollen. Roentgenograms revealed activity in the bone lesion, with effusion in the knee. Amputation was advised, but was refused. In January 1938, three years and four months after synovectomy, the knee was still worse. Roentgenograms (Figs. 7-A and 7-B) showed increasing involvement, and amputation was again advised. A few days later, six years after the original operation, he sustained a pathological fracture through the cyst in the lower femur and developed a severe anaphylactic reaction. He was taken to a hospital in Brooklyn where amputation was performed. Request for half of the specimen was not granted.

The patient was last seen in October 1942. The amputation stump was well healed, and there was no evidence of echinococcus disease in the stump, or elsewhere in his body. He died of cardiovascular disease in July 1943.

SUMMARY AND CONCLUSIONS

The development of our knowledge of echinococcus disease has been outlined, and its etiology and distribution have been described. The disease is rare in this country, but not uncommon in other areas, and its increase may be expected because of conditions growing out of the War. Its diagnosis, especially in bone, is not difficult, if its possibility is realized, and if proper laboratory tests and roentgenograms are made. Treatment has been unsatisfactory to date. Marsupialization or sterilization of the cyst sometimes may be

FIG. 7-A

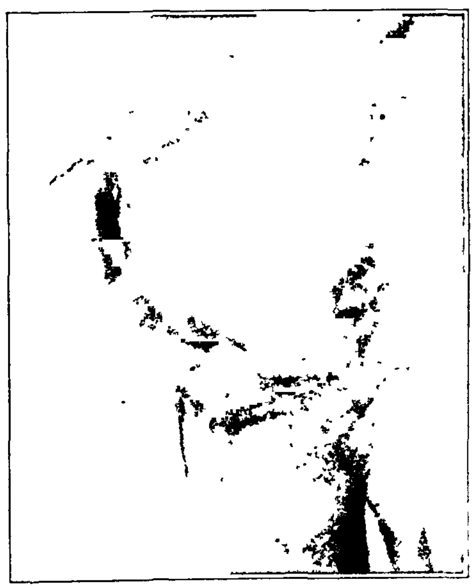

FIG. 7-B

January 15, 1938. Moderate destruction of both femoral condyles has occurred, especially distally, with erosion and collapse of the cortex distally and posteriorly. Soft-tissue swelling is very marked and dense.

successful. Roentgen radiation has failed. Removal of the entire diseased area has removed the disease, but is mutilating. Insertion of bone chips will not be successful, unless the disease has been eradicated.

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ANALYSIS OF ONE HUNDRED CONSECUTIVE ARTHROTOMIES FOR TRAUMATIC INTERNAL DERANGEMENT OF THE KNEE JOINT

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INTRODUCTION

This analysis is based on selected clinical material in the files of a mutual assurance company, existing primarily for the benefit of mine workers. So much in advance of existing legislation and state hospitalization has been the medicolegal and industrial-surgical practice of this company, that many of the recent advances in medicine in South Africa can now be traced to its progressive methods.

MATERIAL

In the especially designed industrial hospital in which this study was undertaken, the major traumatic surgery for 40,000 European male employees is carried out by a staff of full-time and part-time salaried specialists. Clinical records are dictated at the time of examination, operation, and follow-up examinations, and are then typed, filed, and cross-indexed.

Of some 8,000 injuries reported during a year, a considerable number are knee injuries,—such as penetrating wounds of the joint, contusions, fractures, and ligamentous injuries. For the purposes of this investigation, 100 consecutive arthrotomies for traumatic internal derangement performed during 1939–1940 were chosen. This number represents only about one-third of the arthrotomies performed during that time, but the series has the virtue of having been dealt with according to a pre-arranged routine of examination, operation, and after-treatment by one surgeon (G. T. du T.). Final assessments of disability were made by the surgeon, affirmed or altered by the senior consulting surgeon, and checked by the administrative medical officer and his staff.

Most of the employees worked underground at deep rock mining, which involved travel by cage down to 6,000 feet, crawling on hands and knees in low stopes twenty-eight inches high, and sliding along on bellies or buttocks over wet, irregular, slippery rock faces which slope up to 40 degrees. They wore heavy leather boots with metal-studded soles; any other footwear was forbidden by regulations. Hazardous barring down of unsafe rock, dodging of falling rock, moving scrapers, cocopans, slipping on wet metal rails or wooden supporting sprags,—all constituted special dangers and required normally functioning knees.

An injured miner who feels himself unable to carry on does not hesitate to report himself sick, since adequate medical attention, plus 60 per cent. of his wages, as well as subsequent surgical attention by a specialist, is provided. Following operation, an *ex gratia* payment in cases not entitled to permanent disability benefit compensates for most of the loss of wages.

Arthrotomy was not performed until a definite diagnosis of internal derangement had been made. Doubtful cases were treated conservatively by physiotherapy, pending later re-assessment. Very few of these men were allowed back underground for a trial period, while the diagnosis was uncertain.

ROUTINE OF EXAMINATION

For the purpose of examination, the patient was stripped and dressed in a pair of trunks. The following points were tested by the surgeon and recorded by a typist. This

was found to be the only accurate method of keeping records of the examination. The findings of the normal knee were used as a control wherever possible.

Passive extension was tested by forcing the knee into full extension, and noting the site of the pain. Loss of full extension was never found to be painless.

Passive flexion was tested by pushing the patient's heel to his buttock. Limitation of this movement was rarely significant, since even slight effusion produces such limitation.

Effusion was tested by fluctuation and patellar tap.

Patellofemoral crepitation was determined by moving the patella up and down, and sideways on its femoral groove.

Joint crepitation was discovered by moving the joint in the normal manner without weight-bearing, and by palpating the joint during the process. Very frequently, the patellofemoral crepitus would be present with a perfectly smooth main joint.

The tibial collateral ligament was tested in full extension by passive straining of the fully extended knee joint, and degrees of laxity were assessed with a +, indicating the minimum undue laxity, and +++ indicating a complete rupture.

The fibular collateral ligament was examined in the same manner.

The anterior and posterior cruciate ligaments were tested with the patient lying on his back, the knees flexed to a right angle, and the surgeon sitting on both feet of the patient and rocking the head of the tibia backward and forward. Undue *forward* sliding of the tibia was interpreted as anterior cruciate laxity, and undue *backward* displacement of the tibia as posterior cruciate laxity. It was kept in mind that during these tests the musculature had to be completely relaxed. This was usually effected by drawing the patient's attention to something else. The absolute absence of laxity was called normal, but there can be no doubt that knees, capable of perfect physiological function, may nevertheless have slight anteroposterior mobility according to this test. Such knees were classified under + laxity. At operation, it was discovered on several occasions that complete rupture of the anterior cruciate ligament had only been given ++, instead of +++, at preoperative examination by several observers. Attention is drawn to the fact that when the collateral and posterior cruciate ligaments are intact, complete rupture of the anterior cruciate may be masked to a certain extent.

Internal Rotation of the Tibia: This manoeuvre was first demonstrated to the authors by Fouché, who has taught it to several generations of surgeons. It has been a source of interest to visiting military orthopaedic surgeons from abroad, and we have come to regard it as an invaluable contribution to the diagnosis of internal derangement of the knee. The test is carried out on the right knee, with the patient flat on his back on a couch, with his hip and knee fully flexed. The left fingers of the examining surgeon are held on the anteromedial joint line, the right hand firmly grasping the patient's right foot, which is used as a lever in internally rotating the tibia on the femur. The motion is carried through as a complete circumduction movement, starting with the knee fully flexed, and ending with it slightly flexed. The menisci move with the tibia, and the posterior end of the medial meniscus is nipped between the femoral and tibial condyles, the tendency being for the femoral condyle to force the meniscus toward the center of the joint. It may move a small distance, and then slip back, producing an audible and palpable thud. With practice, one is able to recognize this normal thud, and to distinguish it from other sounds. The sound which a torn meniscus may produce varies with the type of tear. From a grossly torn and frayed meniscus may be elicited a crunch or squelch; from a narrow bucket-handle strip of cartilage, a high-pitched click; or from multiple splits in the posterior part of the meniscus, a succession of clicks. A broad rim of meniscus which is partly loose may cause only exaggeration of the normal thud; while the reduction or the dislocation of a wide bucket-handle portion causes a loud crack and a jolt. This test should be distinguished from the McMurray sign, in which the knee is held in full flexion, with the tibia in external rotation, and then gradually extended until a click occurs as the medial

femoral condyle crosses the lesion in the meniscus. The manoeuvre we describe is just the reverse, in that it does not re-duplicate the strain which produces the original lesion, as the McMurray test is supposed to do.

External Rotation of the Tibia: The manoeuvre for internal rotation of the tibia is reversed for the detection of lesions of the posterior half of the lateral meniscus. For this purpose it has been found to be of considerable value.

Manipulation of the Knee in 20 Degrees of Flexion: This manoeuvre is carried out with the patient's knee relaxed. The examiner puts one hand on either side of the joint, and circumducts the knee in a small circle, meanwhile holding his thumbs on the joint line on either side. Although the results of the previously described manoeuvre may have been negative, by this method, it is often possible to elicit thuds or clicks, due to tears situated farther forward, near the anterior attachments of the menisci.

Manipulation under Anaesthesia: This examination was rarely resorted to, and usually gave very little help. When the diagnosis remains in doubt after adequate clinical examination, one feels safe in assuming that the internal derangement, if any, is not sufficiently severe to warrant arthrotomy. The surgeon can learn to distinguish between the various sounds in the relaxed knee of a cooperative patient. The pain associated with the normal sound is usually of value in diagnosis, and anaesthesia robs one of this evidence. (Incidentally, a completely negative manipulation does not necessarily imply a normal meniscus, nor exclude the possibility of a completely displaced bucket-handle portion lying in the intercondylar notch.) In a few cases where manipulation was not possible because of the patients' remonstrances, and where the evidence presented by the other signs and the history was inconclusive, subsequent events proved that operation was unwise on any grounds except an absolute clinical diagnosis. When the diagnosis is uncertain, it is better to defer the decision. The pain in a fresh, severe injury may be genuine; but, in injured workmen, a certain amount of scrimshanking may be suspected.

The site of pain in the knee was determined by asking the patient to point it out, and then testing individually the four attachments of the collateral ligaments, and the four quadrants of the joint line by direct pressure. Tenderness in the anteromedial joint angle is always a very significant finding, and will be discussed later in the paper.

Crushing Sign: In testing for laxity of the collateral ligaments, it was soon discovered that pain was often elicited over the torn medial meniscus by adduction of the tibia on the femur as a result of crushing the torn and painful tissue. Abduction in turn elicited pain when the lateral meniscus was torn.

Mensuration: The routine measurements of the circumferences of the limbs were taken at points measured from the anterior superior spine, usually at the mid-thigh, suprapatellar, joint-line, and mid-calf levels, with the legs relaxed on the couch. With but one examiner, individual variations were excluded.

Reflexes: Knee jerks, ankle jerks, and plantar response were tested as a matter of routine.

The mouth and throat were always investigated for focal sepsis.

OPERATIVE TECHNIQUE

Preoperative skin preparation was carried out for seventy-two hours, as a gesture to the orthodoxy of surgical practice. The writers believe that joint surgery is safe through skin, thoroughly cleansed with soap and water twelve hours before operation, completely shaved, and prepared with any one of a number of skin antiseptics. In this series, tincture of merthiolate was used for the final preparation, 70 per cent. alcohol being used for the previous five preparations. Since the work had a medicolegal aspect, it was felt that, in the event of septic complications of knee operations, the surgeon might not have the support of the "old school", should the preoperative preparation depart radically from orthodox practice.

TABLE I

FINDINGS REVEALED BY MANIPULATIVE EXAMINATION IN SEVENTY-NINE CASES

Lesion	Sound Diagnosed As Pathological	Sound Doubtful	Soundless Manipulation
Bucket-handle tear	18	6	23
Posterior horn, marginal	1	0	1
Posterior horn, tag	6	1	1
Anterior horn, marginal	2	0	0
Anterior horn, tag	1	0	0
Multiple lesions	5	4	4
No tear	2 *	4 *	0
Total	35 (44 per cent.)	15 (19 per cent.)	29 (37 per cent.)

* In these cases the findings on manipulation were misleading. See Table VII.

In the ward, a locked knee joint was invariably kept on a pillow in order to prevent ligamentous strain.

General anaesthesia, a bloodless field, and a non-touch technique were employed throughout the series. A longitudinal parapatellar incision across the joint line was employed for medial meniscectomy; and, for removal of the lateral meniscus, the oblique downward and forward incision, through the fascia lata, was found to give adequate approach, to interfere least with the extensor aponeurotic structure, and to be easily sutured, the edges falling together when the knee was extended.

Subcutaneous bleeding points were ligated. The infrapatellar branch of the saphenous nerve was invariably divided by medial incisions, and the anatomically constant extrasynovial artery (branch of the highest genicular artery) was sutured before the joint was opened.

The incision into the synovial membrane was made from the medial border of the patella to the tibial joint line, thus allowing adequate inspection of the joint. This inspection was carried out in a routine manner by first noting the character of the fluid, then pulling on each meniscus with a blunt hook to test for mobility. By retraction the patellar articular surface was inspected directly for evidence of traumatic lesions of the cartilage. By retracting the infrapatellar fat pad, the opposite side of the joint was examined. In four cases in this series, it was impossible to see the lateral meniscus from the medial side because of an almost complete synovial septum in the middle of the joint.

In bucket-handle lesions of the meniscus, the peripheral margins were invariably dissected out also, in order to avoid missing secondary longitudinal splits in the posterior third. After the peripheral synovial attachment had been freed at its line of reflection with a straight tenotomy knife, the marginal portion could usually be displaced into the intercondylar notch.

When osteochondritis dissecans was discovered, a few drill holes were made into the bare-bone floor of the lesion. The wound was closed in layers, and a very large wool dressing was applied in moderate tension. The dressing was designed for comfort, rather than for purposes of minimizing postoperative extravasation.

Postoperative Routine

The foot of the bed was raised on eight-inch blocks. On the second day, active foot and ankle movements were started, and on the third day, active quadriceps contractions were begun. Straight-leg raising, ten times per hour, was initiated on the fourth day, and active flexion to the extent permitted by the dressing was allowed on the seventh day. On the twelfth day, the stitches were removed, and the patient was seated in a wheel chair. Thus the knee was unconsciously flexed to 90 degrees. The quadriceps drill was maintained. The patient was usually able to lift his knee 200 times at a sitting on the four-

teenth day; and beginning at this time, he was allowed to attempt walking with the aid of a cane. On the sixteenth or seventeenth postoperative day, the patient was formally discharged, but continued in daily attendance in the out-patient department, travelling by bus or tram to the hospital. From the fourth week, the patient was instructed to swim, ride a bicycle, do antigravity weight-and-pulley exercises, or stationary row-boat exercises, and to walk several miles daily. Work was usually resumed at the end of the sixth or the seventh week.

The follow-up of these patients depended upon the fact that each man was told that, *if the knee gave any trouble whatsoever, he was to report to the medical officer of his* own mine, who would then refer him to the head office for re-examination, further treatment, or final assessment of disability. It is now four years since the last case in this series was treated.

OPERATIVE FINDINGS

Of the lesions found at operation, eighty-two were tears of the medial meniscus, nine were tears of the lateral meniscus, and three patients showed medial and lateral tears in the same knee. Two knees had discoid but untorn menisci, and there were four cases in which no lesion of the meniscus was discovered.

Of ninety-seven torn menisci, forty-nine were bucket-handle. This high percentage (50.5 per cent.) is accounted for by the postponement of operation until diagnosis of meniscal lesion was quite certain.

On the basis of systematic examination of intra-articular structures at operation, and of prompt recording of findings, we are able to state that multiple lesions were common, and often included traumatic degenerative arthritis.

There were two patients with osteochondritis dissecans and many with traumatic lesions of the cartilage of the medial facet of the patella,—the so-called "hot spot", associated with the name of Fouché, our pioneer orthopaedic surgeon.

Diagnostic Sounds

Manipulative examination revealed the findings in Table I.

Pain

Pain at the joint line was recorded in ninety-nine knees,—198 medial and lateral sides. Ninety-six sides had torn menisci, and 102 had healthy menisci, as judged by operative and follow-up findings. Of the ninety-six torn menisci, ninety-three had pain over the same side, and three patients did not suffer pain.

In six cases erroneous diagnoses were made. This led to unnecessary arthrotomy in two cases (one had pain at the medial joint line and a strained tibial collateral ligament, but no cartilage tear; the other had medial joint-line tenderness, a contused infrapatellar fat pad, and no cartilage tear). An unnecessary extra incision was made in two cases (one had bilateral pain with a lateral cartilage lesion; the other had a tear of the lateral meniscus, strain of the tibial collateral ligament, and medial pain). Two knees had discoid but untorn menisci.

In four cases of bilateral pain, a unilateral lesion was diagnosed correctly from positive manipulative findings, and preponderance of tenderness on the side of the lesion. In two cases, bilateral meniscal tears occurred with unilateral pain.

In two cases, diagnoses of meniscal tears were made in spite of the absence of pain at the joint line. *Both proved erroneous!*

Since tenderness due to ligamentous strain is typically elicited at the upper or lower bony attachments, pain on pressure at the joint line, just in front of or behind either collateral ligament, must be carefully sought for. When positive, this sign is valuable; when negative, arthrotomy should be postponed, unless the other diagnostic findings are conclusive.

TABLE II
INCIDENCE OF LOCKING

Lesion	History of Locking *Number of Cases*	No History of Locking *Number of Cases*
Bucket-handle tear	55	8
Anterior, marginal tear	2	0
Anterior horn, tag	1	0
Posterior, marginal tear	1	4
Posterior horn, tag	1	7
Multiple tears and unusual types	8	7
No tear	1 (Case 99)	5
Total	69	31

Contralateral pain is questioned as a diagnostic finding. Of nine patients with tears of the lateral meniscus, six had lateral joint-line pain, two had bilateral pain, and one had medial pain. This last case and one case with bilateral pain had concomitant strain of the medial collateral ligament.

Locking

Locking for the purpose of this investigation was defined as a mechanical block to free extension of the joint. Unlocking was never deliberately attempted; although, in the course of manipulative examination, four of the series unlocked with a thud which was recognized as pathological, and, therefore, was diagnostically significant. Out of a total of fifteen cases with bucket-handle tears and a loss of extension of 15 degrees, eleven did not unlock, and they were soundless on manipulation. A marginal posterior tear caused locking, which could be unlocked with a click on kicking the leg straight. Similar momentary locking was caused in another case by a small tag of meniscus. In a third case, a torn stump of anterior cruciate ligament was responsible for locking. Case 87 is an example of this condition.

CASE 87. A man reported two days after injury that "while travelling in a skip, the hoist tripped out" and he had jarred his hip and knee slightly. He stated that his knee gave him no trouble. However, seven months later, in changing his position while squatting, the knee locked suddenly and painlessly for the first time. Operation revealed a bucket-handle medial meniscus.

From the medicolegal point of view, it should be accepted that a very minor trauma may produce a torn meniscus. Although clinical manifestations following trauma may be delayed for months, lack of pain does not exclude the possibility of a tear.

Several patients were unable to extend the knee immediately after injury, but straightening gradually took place; therefore, these cases were counted as without locking. In some patients, definite cartilage lesions capable of locking were found; in others, a contused infrapatellar fat pad; and, in some, pain alone appears to have been adequate explanation for inability to extend the knee. Table II shows in detail the relation of locking to the various types of lesions found.

In the positive cases, the cause of locking, as far as could be determined, was as follows: Of sixty-nine cases, the meniscal lesion was responsible in fifty-nine; in eight cases, either a meniscal lesion or a nipped infrapatellar fringe was the causative factor; in one case a pedunculated fatty mass attached to the middle of the anterior cruciate ligament was the cause (there was also a meniscal lesion which could not have caused locking); in another case a discoid meniscus may have been at fault, but it is probable that the patient (Case 99) gave a misleading story.

CASE 99. This man reported the fourth day after injury. On that day he told the examiner that he had rolled fifteen feet down a slope, and bumped the inner side of his knee against a sprag, but that he was not quite sure as to what had happened to his knee. On the ninth day, he reported that when he

straightened his knee after sitting on his haunches, he felt a crunching thud momentarily. On the twenty-third day, he said that, after rising from his haunches, there was a click in the knee, and subsequently he was unable to straighten his knee. Examination revealed no limitation of extension. At operation, a discoid lateral meniscus was evident, without a tear.

There was also difficulty in analyzing the sign of limitation of passive extension, and there were a number of difficult borderline cases. (See Tables III and IV.)

TABLE III

PATIENTS WITH MENISCAL LESIONS SHOWING LIMITATION OF PASSIVE EXTENSION

Degree of limitation of extension	0	5	10	15	20	25	40	45	50	90
Number of Cases (Total 93)	27	28	21	6	4	3	1	1	1	1

TABLE IV

PATIENTS WITH LIMITATION OF EXTENSION NOT DUE TO MENISCAL LESION

Limitation of Extension (*Degrees*)	Nipped Synovial Fringes	Pedunculated Stump of Anterior Cruciate	Absence of Mechanical Obstruction
5	2	1	2
10	0	0	3

In eight out of sixty-six cases with limitation of extension, the meniscus was not the cause. These cases are analyzed in Table IV.

All of the patients included in Table IV had pain at examination when extension was forced, and in five cases, the forced extension was clearly the sole cause. We are not aware that a portion of the anterior cruciate ligament has been previously considered as a cause of internal derangement. Since then we have noted this finding in two additional cases.

A longitudinal meniscal tear with a bucket-handle portion in the intercondylar notch may cause limitation of extension of varying degree, depending upon how far forward the tear extends. In one case locking occurred with loss of extension of only 5 degrees. If the tear extends so far forward that the medial condyle of the femur moves throughout its course within the gap in the meniscus, there is no loss of extension. Ligamentous laxity may mask obstruction.

In each of seventeen cases with 15 degrees or more of limitation, the meniscus was torn in such a way that it might have caused the block. Fifteen of these lesions were bucket-handle tears, whereas, had this group of seventeen been representative of the whole series, there would have been only nine cases of bucket-handle tear.

We conclude that a limitation of extension of 5 degrees is not significant; 10 degrees is suggestive, but limitation of 15 degrees is almost certainly due to a mechanical block, caused by a meniscal lesion or a loose body.

TABLE V

ANALYSIS OF PATIENTS WITH WASTING OF THE QUADRICEPS

Period elapsed since injury	1–10 Days	11–100 Days	Over 100 Days	Total
Low thigh circumference less than uninjured thigh, therefore, wasting present.	29 cases (37 per cent.)	4 cases (5 per cent.)	8 cases (10 per cent.)	41 cases (52 per cent.)
Thigh circumference same as uninjured thigh, therefore, wasting not present.	18 cases (23 per cent.)	15 cases (19 per cent.)	4 cases (5 per cent.)	37 cases (47 per cent.)

TABLE VI

CREPITATION FOUND IN CONJUNCTION WITH OSTEOCHONDRITIS OF THE PATELLA

	"Hot Spot" 21 Cases	No "Hot Spot" 79 Cases
Patellofemoral crepitus present	72 per cent.	20 per cent.
Patellofemoral crepitus absent	28 per cent.	80 per cent.

Wasting

In clinical teaching, wasting has long been considered as a typical occurrence accompanying meniscal lesions. This wasting usually occurs very rapidly, even within a few days. It has been held that the absence of wasting excludes the diagnosis of serious intra-articular lesions.

The seventy-eight cases with meniscal tears, and on which data on circumferential measurements of thigh and calf were available, were divided into groups according to the period which had elapsed since injury (Table V). Three-eighths of an inch or more of reduction in circumference was arbitrarily labeled wasting.

In two cases which showed wasting, it was proved at arthrotomy that no lesion existed, other than a strained medial collateral ligament, and a nipped synovial fringe, respectively. It is common knowledge that a wide variety of lesions of the knee, minor and major, may lead to wasting.

We conclude that, while the presence of wasting may be of contributory diagnostic value, *the absence of wasting does not necessarily preclude meniscal damage,* irrespective of the delay between examination and injury. From the medicolegal standpoint, this is a significant observation. How often has the patient's word been doubted, because of absence of wasting in the presence of gross meniscal damage!

Patellofemoral Crepitus and Degenerative Arthritis

In 21 per cent. of this series, arthrotomy revealed an area of degeneration of the articular cartilage on the medial facet of the patella. The early appearance is that of softening and swelling of the cartilage, which looks sodden, and pits on pressure with a blunt point. Later the apex of the swelling separates, leaving a crater down to bare bone.

In our opinion, this is the site of the first appearance of degeneration of the articular cartilage in the knee joint. It is commonly seen in arthrotomies for lesions of the medial meniscus, and often occurs in patients who are not miners.

Clinically, patellofemoral crepitation may be velvety and synovial, or grating and associated with gross articular damage.

Analyzed in relation to traumatic lesions of the patella revealed at operation, our findings appear in Table VI. It will be seen that synovial crepitation frequently existed

TABLE VII

ANALYSIS OF THIRTEEN POSTERIOR MENISCAL TEARS

Type of Lesion	History of Locking	Limitation of Extension	Positive Manipulative Findings
Tear of posterior horn	17 per cent.	0 at 15 degrees 23 per cent. at 10 degrees	70 per cent.
All other lesions in the series	77 per cent.	22 per cent. at 15 degrees 25 per cent. at 10 degrees	38 per cent.

TABLE VIII

Cases in which Erroneous Diagnoses Were Made

Case History	Case 22	Case 53	Case 61	Case 99	Case 60	Case 84	Case 8	Case 83
Pathology found	None	None	Discoid medial meniscus	Discoid lateral meniscus adherent to tibia	Osteo-chondritis	Large nipped synovial fold	Bucket-handle tear of lateral meniscus	Bucket-handle tear of lateral meniscus
Preoperative diagnosis	Internal derangement. Medial incision advised	Tear of medial meniscus	Torn medial meniscus	Torn displaced lateral meniscus	Torn medial meniscus	Torn displaced lateral meniscus	Bucket-handle tear of medial meniscus	Torn medial meniscus
History of locking	No	No	No	Yes	No	No	Yes	Yes
Significant limitation of extension	None	None	None	None	None	None	None	None
Pain at the joint line	No	Yes	Yes	Yes twice No once	No	Yes	Bilateral	Medial only
Diagnostic sounds at manipulation	No twice Yes once	No twice Yes once	Yes	Yes 4 times ? once	No once Yes once	Yes	No	Yes crunch medially
Wasting	Yes	No	No	No	No	Yes	Yes	Yes
Crushing sign	Yes	No	No	No	No	No	No	No
Effusion	None present, later after a walk	Slight	Present	None	Slight	None	?	Present
Doubt in the diagnosis	Yes	Yes	No	Yes	Yes	No	No	No
Tibial collateral strain	Yes	Yes	No	No	Yes	No	No	Yes

in conjunction with these changes in the cartilage, although they were sometimes found without clinical signs.

Crushing Sign

In seventeen positive cases—that is, with pain present over the meniscus which is compressed by adduction or abduction of the tibia—there was one case without a meniscal lesion. It is not, therefore, as pathognomonic a sign as our clinical impression had led us to believe.

Posterior-Horn Lesions

In this group, accurate preoperative diagnosis is the basis upon which meniscectomy is performed. When the knee is opened anteriorly, the meniscus looks and feels firm on being pulled upon; nothing abnormal is noted. Nevertheless, one should proceed with the meniscectomy, for, after detaching the anterior end, and while proceeding with the marginal separation, a long tag or a posterior tear will suddenly be demonstrated far back. Thus the meniscectomy is justified.

In our experience, it has been a mistake to close a joint without first removing the meniscus, once a lesion has been definitely diagnosed. The only exception to this practice is when gross ligamentous laxity allows full inspection of the suspected meniscus.

In Table VII will be found an analysis of thirteen posterior meniscal tears. This shows that locking is infrequent; and in this group locking is often followed by unlocking. Positive manipulative findings are common and valuable in determining the site and the side of the lesion.

Marginal Lesions

Marginal lesions are alleged to heal often with conservative treatment. In this series it was accepted that conservative treatment prevented the patient from working, because there was no "light work". In only seven cases out of ninety-four, were there tears through vascular, peripheral parts of the meniscus. Therefore, operation was justified in eighty-seven by the lesion, and in the other seven by the fact that time was undoubtedly saved, and recurrence was avoided. In three of the seven cases there were subsynovial tears,—that is, although there was no open split between the meniscus and the capsule, a synovial fornix dipped down between them, and the meniscus, when pulled upon, slipped well into the joint. In two of the three cases, hemarthrosis verified the intra-articular trauma.

Investigation of seven cases with marginal tears revealed no pathognomonic sign. Easy locking and unlocking, manipulative findings, and joint-line tenderness were all too variable to be of specific diagnostic value. Three of these patients tried working for one, one and a half, and five months, respectively, but in all cases arthrotomy was finally necessary. We believe that, once a meniscal lesion has been diagnosed, even one trial of conservative treatment is unjustifiable.

Erroneous Diagnoses

In Table VIII are grouped eight cases which were erroneously diagnosed, some of which have been mentioned separately under previous headings.

In the six cases where a meniscus was not torn, the decision to operate was usually based on (1) the failure of a trial of use of the knee, and (2) the manipulative findings. The latter, in four cases, though finally accepted as positive, were equivocal in that they varied at different examinations. It should be emphasized that in some cases, despite an incorrect diagnosis, arthrotomy was justified. In this group of erroneous diagnoses, two noteworthy features were the doubt which accompanied the diagnosis, and the frequent presence of strain of the tibial collateral ligament.

RESULTS OF ARTHROTOMY

For purposes of comparison, a number of cases were chosen in which, apart from the meniscal tear, there were no pathological changes detectable, clinically or at operation,

TABLE IX

RESULTS OF ARTHROTOMY

Complications	No. of Cases	Patients Receiving Compensation No.	Per cent	Average Compensation Per Capita for Permanent Disability	Average Number of Days from Work after Operation
"Uncomplicated" group	14	0	0	0 per cent.	49
Postoperative sepsis; septic arthritis severe	2	2	100	15 per cent.	127
Postoperative sepsis; septic arthritis mild	3	2	67	3.3 per cent.	99
Degenerative arthritis; well marked	3	3	100	11 per cent	58
Laxity of ligament; well marked	5	5	100	4 per cent	66
Well-marked post-operative effusion	6	2	33	1.1 per cent	50
Nipped fringes at operation	8	2	25	1 per cent	53
Degenerative arthritis; slight	13	4	27	0.8 per cent	50
Concomitant medial ligament strain	6	2	33	0.8 per cent	53
Laxity of ligament; slight	13	0	0	0 per cent	47

where the operation involved only one standard incision, and where there were no post-operative complications.

The results in this group of fourteen patients, as compared with those with various complicating factors, appear in Table IX.

CASES WITH COMPLICATIONS

The three most serious cases in this series of cases with complications are described in detail, as it is felt that they are of unusual interest.

CASE 8. An underground miner, thirty-five years old, worked for five months with the lateral meniscus completely "bucket-handled" into the notch. Eighteen days prior to the operation the patient had had a complete dental clearance for pyorrhoea. Two incisions were used in the operation. On the third postoperative day, the patient's temperature was 100 degrees, his pulse was 84. There was unusual postoperative pain, and the superficial subinguinal glands were tender. On the sixth day, the temperature was 101 degrees; the pulse was 96. The patient was suffering from throbbing pain. The dressings were removed, and cellulitis around both incisions was observed. All skin sutures were removed, and thick yellow pus was evacuated from both wounds. There was no effusion, and the patient had free joint motion. Laboratory examination showed the presence of pus cells with staphylococcus albus. The granulating area in the mouth was swabbed, and the laboratory reported pus cells, non-hemolytic streptococcus, pneumococcus, staphylococcus aureus, and diphtheroids. The wounds became granulated and healed. The patient was discharged from the hospital on the seventy-ninth postoperative day, and he resumed work 126 days after the operation. He had loss of extension of 5 degrees, loss of flexion of 10 degrees, and quadriceps wasting of one and a half inches. There was some periarticular thickening, and slightly increased laxity of the anterior cruciate. A permanent total disability assessment of 7.5 per cent was made. On examination four years later, the patient's knee was normal except for adherent scars. He had full range of motion, powerful quadriceps, no ligamentous laxity, and absence of joint crepitation.

CASE 99. A learner, twenty-seven years old, following a fifteen-foot fall, was found to have an indefinite derangement of the right lateral meniscus with associated hyperpiesis and albuminuria from long-standing renal disease. A congenitally malformed lateral meniscus, without evidence of trauma, was removed. Operation was followed by oedema around the wound, delay in healing, and subcutaneous collection of fluid communicating with effusion in the joint. Serous discharge broke through the incision, which on culture proved to contain staphylococcus aureus. A few days later thick pus drained directly

from a sinus in the knee. Later swabs were sterile, although the temperature was 102 degrees and the pulse was 120. Moderate pain on passive movement confirmed the diagnosis of infectious arthritis. The sinus healed by granulation, and the patient resumed work 103 days after the operation. At that time, there was no effusion. He had one inch of wasting of the quadriceps, slight periarticular thickening, and range of motion from 180 degrees to 60 degrees. There was a permanent total disability assessment of 15 per cent.

CASE 32. An underground-shift boss, thirty-two years old, had a bucket-handle medial meniscus removed, following several weeks of treatment for a slightly pustular skin condition. Eight days after operation, the patient's urine was very thick, and it contained pus cells, phosphates, and abundant staphylococcus albus. The temperature was 99 degrees; the pulse was 96. The patient had a slight chill. On the tenth day, the dressing was removed for the first time, and, as the stitches were taken out, a considerable quantity of pus welled out of the center of the wound. This contained hemolytic staphylococcus aureus on culture. Until then the patient had not complained of pain in the knee, nor was there any effusion. On the twelfth day, there was extensive effusion and excruciating pain on the slightest motion. Diagnosis was made of acute suppurative arthritis. The patient resumed work 150 days after operation, the knee having a range of motion from 175 degrees to 85 degrees. There was no increase in preoperative laxity of the ligaments, no effusion, and only slight patellofemoral crepitation. There was some limitation of internal and external rotation of the flexed tibia, and one inch of wasting of the thigh. A permanent total disability assessment of 15 per cent. was granted. (Our usual assessment for bony ankylosis in the optimum position is 30 per cent.)

Cases of degenerative arthritis were due sometimes, but by no means always, to the wear and tear of an aging joint. In a few cases, the repeated traumatic effect of a long-neglected torn cartilage was clear. In others, there was obvious evidence of trauma to the articular surfaces, due to the injury itself, as in the following case.

CASE 83. The man reported: "I stepped back, tramped on a block, and my knee twisted. I fell and had a severe pain in my knee. Then as I bent my knee, I heard a grating noise." There was no previous injury. At operation eight days later, the articular surfaces of both the femoral condyles and of the lateral tibial condyle were found to be damaged. In places they were broken into innumerable small fragments, some of which were loose. The lateral meniscus lay in the notch, torn in a bucket-handle manner. This case was later assessed at 10 per cent. of permanent disability.

Mild arthritis was a complicating factor in traumatic lesions of the cartilage and similar minor lesions.

There were sixteen cases of gross laxity, but in assessing the effect of this factor, all but five cases were discarded, due to the coexistence of one or more other complications. In thirteen of these cases, the laxity was anteroposterior, solely or predominantly. Of the cases with well-marked laxity, 42 per cent. also had definite arthritis of mechanical origin; while 8 per cent. of cases without well-marked laxity had this type of arthritis.

A severe postoperative effusion in one case in the series led to the formation of a sinus, which discharged sterile fluid for three weeks. In another case, passive flexion administered by a new masseur caused rupture of the suture line in a joint already over-distended with fluid. Our present routine is to apply three or four thick sheets of sterile cotton wool around the limb from mid-calf to mid-thigh, with a six-inch bandage to compress each layer of wool separately and firmly.

The penalty of delay varies with the type of tear. In the following case, the erosive effect of what originally was, in all probability, a taglike tear was considerable.

CASE 59. The patient was thirty-one years old. Operation was performed after a delay of six years. The medial meniscus was found to have a complete tear, somewhat transversely at its middle; the edges were rounded off, showing it to be an old lesion. The posterior half could not even be seen. There was extensive osteo-arthritic lipping of all articular surfaces; extreme erosion of the articular surface of the femur extended down to the center of the bone in the center of the condyle. Through a separate posterior incision the back half of the meniscus was removed. There was disability of 15 per cent.

On the other hand, the following case in which a bucket-handle tear was found, shows the effect of less frequent traumata.

CASE 5. The patient was twenty-five years old. There had been a two-year period of delay, during which time the knee "had been out on several occasions". There was roentgenographic evidence of early arthritis. At operation no damage to the articular cartilage was found, but the synovial membrane was injected. Three months after the operation, there was well-marked joint crepitus. Disability was assessed at 2.5 per cent.

The patients in the top age group (forty to fifty years) did not fare quite as well as did the patients in the lower age group. One patient received compensation; the average disability per capita was 0.4 per cent.; and the average number of days off work after operation was fifty-two. Certain older patients showed preoperative evidence of arthritis,—one slightly, and four moderately. The youngest patient in our whole series was seventeen years old, and he recovered in twenty-six days, although the average recovery time for his age group was forty-eight days.

COMPENSATION

Compensation assessments were normally made after the man had been continuously at work for two months after operation. All claims were then settled. By law the man is entitled to later apply for re-examination and re-assessment, if he feels that the knee condition has deteriorated. Although four years have now elapsed since the last patient in this series resumed work, there have been no applications for increased assessments.

Of the 100 cases, twenty-seven men received some compensation, varying between 2.5 per cent. and 15 per cent. The average for the whole series was 1.6 per cent. Because an empirical standard is usually set by current practice in non-scheduled assessments, the following illustrative cases are given to show the broad basis used for comparison.

Assessment of 2.5 per cent.

CASE 35. An "occupation fitter", thirty-four years old, had spent two years underground. Ninety days after the injury there was wasting of seven-eighths of an inch. At operation for removal of the left medial meniscus, there was no evidence of arthritis. The patient failed to report for work for sixty-eight days after operation. Four and a half months after operation, he complained of tiredness in the leg after working, and there was wasting of one and a quarter inches. The patient had not missed a shift since resuming work. There was full range of motion, no ligamentous laxity, no effusion, and no crepitation. There was a diagnosis of quadriceps insufficiency, and it was decided that the patient was a lazy fellow.

Assessment of 10 per cent.

CASE 83. The patient, a painter, thirty-three years old, worked above ground, and showed moderate laxity of the medial collateral ligament. Mild osteo-arthritic changes were evident at operation for removal of the right lateral "bucket-handled" meniscus. Two incisions were made, since the diagnosis of a lesion of the medial meniscus proved incorrect. A low-grade infectious arthritis followed operation, and the patient failed to report for work for fifty-one days. The disability assessment was made after one month at work, when the patient stated that he had "pain at the end of a day's work, but not in the morning". There was then moderate joint crepitation, gross laxity of the anterior cruciate and medial collateral ligaments, one inch of quadriceps wasting, full range of movement, and no effusion.

Assessment of 15 per cent.

CASE 59. The patient had been an underground stoper for twelve years. He was thirty-one years old. There was gross laxity of the anterior cruciate ligament, and wasting of two and a quarter inches of the quadriceps. The knee had troubled the patient for 178 days previous to the operation. Roentgenographic evidence of extensive osteo-arthritis was confirmed at operation, and there was crepitation of both the patellofemoral and main joints. Transverse tears of the medial meniscus and of the posterior horn were evident. There was erosion of the cartilage down to the bare bone of the medial condyle, and complete rupture of the anterior cruciate ligament. The patient did not resume work for eighty-nine days after the operation. Five months after the operation, he stated: "My knee is sore if I walk some distance; at night there is a dull pain." At examination, well-marked joint crepitation was evident, as well as gross instability of the anterior cruciate ligament. There was one inch of quadriceps wasting, full range of motion, and no effusion.

SUMMARY

1. An analysis has been given of 100 consecutive knee arthrotomies performed on European miners working underground in the Witwatersrand Gold Mines.

2. The routine of clinical diagnosis, operation, and postoperative care has been described.

3. The operative findings have been analyzed. In four cases, no meniscal lesions were discovered at operation; in eighty-two cases, tears of the medial meniscus were found; in nine cases, tears of the lateral meniscus were seen. There were double tears in three cases, and discoid menisci in two. Of ninety-seven torn menisci, forty-nine were of the bucket-handle type.

4. The operative findings have been correlated with the signs found at examination.
   a. Pain at the anteromedial joint line was found to be of considerable diagnostic significance. Absence of such pain contra-indicated arthrotomy for meniscal lesion.
   b. It was shown that locking is frequently, but not always, due to a meniscal lesion. A stub of anterior cruciate ligament was the cause of locking in one case.
   c. Meniscal damage may exist in the absence of wasting.
   d. Fouché's "hot spot" on the medial facet of the patella is described.
   e. The "crushing sign" is found to be not entirely pathognomonic of meniscal damage.

5. Erroneous diagnoses have been analyzed in some detail.

6. The end results of treatment are given, with disability assessments averaging 1.6 per cent. for the whole series.

7. Complications of the operation have been discussed.

8. The penalty of delay in operation has been found to vary greatly according to the type of lesion.

9. The findings in our investigation favor early and total meniscectomy, once an incontrovertible diagnosis has been made.

TRAUMATIC DEGENERATION OF THE ARTICULAR CARTILAGE OF THE PATELLA

BY LIEUTENANT COLONEL RALPH SOTO-HALL

Medical Corps, Army of the United States

The frequency of arthrotomies, performed for the treatment of various types of internal derangement of the knee, has focused attention on lesions of the articular cartilage of the patella in military personnel. It is surprising that pathological changes at this site, which have such a high incidence, and which seem to play such an important rôle in the persistence of symptoms after knee surgery, have received so little attention in the Anglo-American literature. Scandinavian authors have written extensively on this matter during the last few years.[3,4,5,6]

The patella lies in one of the most exposed parts of the body. It has an extremely thick cartilage, the central part of which is poorly nourished. This articular cartilage may suffer either acute or chronic traumatization, leading either to fractures or to delayed changes, which we have interpreted as a result of impaired nutrition.

PATHOGENESIS

While studying amputation specimens obtained after severe injury, we have observed at times recent linear fractures of the articular cartilage without accompanying bone injuries, although careful roentgenographic studies of these specimens did not demonstrate any pathological changes. Such cartilage injuries (similar to those frequently noted in the capitellum of the humerus [capitulum humeri] during the operation for excision of a fractured head of the radius), though usually not clinically demonstrable, may lead to the formation of loose bodies, or to the impairment of the gliding mechanism, with slow disintegration of the cartilage from attrition; this may explain in part the partial fixation of the patella after certain fractures of the femur. Moreover, in the specimens studied, there was often a tearing of the capsular attachment to the patella, which probably resulted in damage to the rather limited blood supply.

Thus, from the direct injury, or from a secondary loss of adequate nutrition, or both, there occurs a pathological state in the cartilage of the patella, which has been designated as chondromalacia patellae or, less appropriately, chondritis (chondropathy). The frequency of this condition can be illustrated by the fact that in sixty-five arthrotomies performed in a military hospital for chronic knee complaints, this lesion of the patella was encountered in twelve cases, representing 18.5 per cent. In six of these patients, the degeneration and erosion were so extensive, and the disability was so pronounced, that total excision of the patella was warranted. The incidence is highest in young adults, the average age in this series being twenty-nine, and the age of the oldest patient, thirty-six years. (We have seen this condition well advanced in a young woman of seventeen, whose case is not included in this study.) This average age may be influenced, of course, by the age of the military personnel, but in our civilian practice we rarely encountered a similar lesion in older individuals.

HISTORY

All patients gave a history of moderately severe trauma,—consisting in six cases of direct contusion; in three, of a twisting injury; and in one, of a linear fracture of the bone. Two had suffered dislocations of the patella, followed by recurrent subluxations. These two patients are of particular interest because, in addition to the lesions in the cartilage of the patella, small loose bodies and an area of advanced cartilage erosion were found on

the lateral femoral condyle, exposing the subchondral bone for about one-half inch. This is a frequent concomitant finding in recurrent dislocation of the patella, and results from repeated trauma and severe friction as the patella rides over the condyle. It should be taken into consideration when corrective surgical procedures are planned. Wiberg, in 1941, described well-advanced chondromalacia in recurring dislocations of the patella, with and without an accompanying congenitally low femoral condyle, and it was noted after dislocation of the patella experimentally by Bennett, Bauer, and Maddock, during their study of repair of articular cartilage in the femur.

The clinical histories followed a somewhat typical pattern. After the original injury, there was a short period of total disability, which was followed by a rather quiescent period of several months in which there were some mild symptoms in the knee. With or without an additional precipitating injury, there was then a gradual development of more severe symptoms, culminating after some months in a marked disability. The course of this syndrome simulates, therefore, the sequence of events seen in post-traumatic aseptic necrosis of bone, when it occurs in various parts of the body.

A typical history is the following:

Case 6. A soldier, twenty-three years old, with approximately two years' service, was first injured in 1937, when the anterior part of the right knee was struck. The patient believes a diagnosis of ruptured ligaments was made, and he spent six weeks in traction, and six months on crutches. Following this, he was able to engage in baseball, basketball, and boxing, with no disability, but with an occasional feeling of impairment, discomfort, and instability in the knee. He entered the Army on August 3, 1942, and underwent the strenuous basic training without difficulty. He was assigned to an engineering unit, and became a jeep driver. In March 1944, while on shipboard going overseas, he was engaged in an exhibition boxing match and twisted the knee. Pain and swelling developed, for which he was hospitalized; his condition did not improve, and it was necessary to return him to the United States. His symptoms consisted of loud popping sounds in the knee, a feeling of instability, and pain located deep in the joint. Examination showed atrophy of one inch at the mid-thigh, although the patient walked without a limp, and had a normal range of motion. When he sat with the knee at 150 degrees of extension, the patella could be displaced laterally, and hooked on the lateral condyle so that it remained in this position. Marked crepitation could be felt under the patella. No effusion was found; a minimal relaxation of the tibial collateral ligament was noted. At operation, the patellar articular cartilage was found extensively involved (Fig. 1), and on the lateral femoral condyle was an area of cartilage erosion, similar in size to that of the patella.

Fig. 1

Case 6. Soldier, aged twenty-three. Operation disclosed extensive involvement of medial facet of the patella, with loose-body formation. A well advanced "mirror image" was also present in the lateral femoral condyle. This type of lesion is produced by recurrent trauma between the lateral condyle of the femur and the patella, resulting from a muscle imbalance in the quadriceps which produces recurrent slipping.

SYMPTOMS

One of the most significant symptoms is that of crepitation associated with certain active movements of the knee, although this may be absent when the disease in-

volves only the most inferior part of the cartilage. Crepitation is not always elicited when the knee is flexed with the patient sitting, and we have found it of value to test the patient in the following manner: Lying upon his back with the hip and knee flexed, the patient is asked to flex and extend the knee gradually without moving the hip. This movement, by its various anatomical relationships, is an assurance that the diseased area will come in contact with the femur. The crepitation can be easily felt by the examiner after he has placed his hand upon the affected knee, and forcibly pressed the patella against the femoral surface. This test is of particular value in the mild and early cases. Crepitation is significant also in those cases where there is instability, due to relative inequality of power between the vastus lateralis and vastus medialis, since in the presence of such imbalance the patella does not follow the intercondylar groove, but impinges against the lateral condyle of the femur. The importance of this imbalance of the patella was demonstrated as early as 1867 by Duchenne who, by applying a strong electrical stimulation to the vastus lateralis, was able to produce outward luxation of the patella, while with stimulation of the vastus medialis, no medial displacement of the patella could be produced. This lateral displacement is explained by the fact that, when the vastus lateralis contracts, due to its axis of pull, it tends to draw the patella outward. In the normal individual this deforming force is countered by the lowermost fibers of the vastus internus, which lie in an axis almost transverse to it. Because instability of the patella may exist in the patient, which may otherwise escape detection, it is important to examine the patellofemoral joint in active motion. Roentgenographic studies of the specimens, as well as various projections of the patella itself have generally failed to show any demonstrable change in the patella. However, by taking axial views of both knees in 60-degree, in 90-degree, and in full flexion, we have been able to demonstrate the abnormal course of the patella as it moves from its central position to be lodged in the intercondylar groove.

FIG. 2

Case 1. This patient, aged twenty-eight, reported symptoms dating back six years to a football injury. He presented laxity of the capsule with recurrent subluxations of the patella and loose-body formation. A very small lesion was present in the lateral femoral condyle.

It is of interest that the patient often has difficulty in describing and localizing the deep-seated pain, a factor which, combined with the pseudolocking or ratchet movement of the knee, often leads to diagnostic confusion. Of the twelve proved cases, four patients had been previously operated upon elsewhere for suspected meniscal injury, but the inaccuracy of the diagnosis was proved by the persistence of identical symptoms and by the subsequent operative findings.

The diagnosis must finally rest on combinations of these signs and symptoms:

1. Subpatellar crepitation on active movement;
2. A variable deep-seated pain;
3. Tenderness on percussion of the patella;
4. A pseudolocking, or ratchet rhythm;
5. A subjective feeling of instability;
6. Occasional recurrent subluxations of the patella.

PATHOLOGY

A review of the various stages in the gross pathology of chondromalacia readily explains the clinical picture. The initial change, soon after trauma, is oedema of the articular cartilage, followed by a certain amount of softening, with subsequent formation of rather characteristic fissures or cracks. (The softening can be demonstrated during arthrotomy by passing a blunt instrument gently over the diseased surface, when a soft indentation can be felt.) That part of the patellar cartilage which is most poorly nourished, the central and medial area, is often the site of the most serious involvement. As fraying of the cartilage and degeneration progress, the fissures develop small fine tufts which remain attached at one end or, more rarely, become free loose bodies (Fig. 4). In the later stages, the subchondral bone is exposed at the base of the irregularly shaped craters, showing its bluish polished surface, in vivid contrast to the adjacent white glistening cartilage. When the disease has been present in the patella for a long period of time, a similar condition develops in the opposing surface of the femur. This secondary lesion may assume the identical size and contour of the parent lesion, and we have termed it a "mirror image", because of its similarity in appearance. Two types of "mirror image" have been observed; one on the lateral femoral condyle, found in those cases presenting subluxations of the patella, and another lying directly between the condyles (Fig. 5), the etiology of which is more difficult to explain. As these small craters in the joint surfaces glide over each other in apposition, they produce the feeling of insecurity, pseudolocking, and the ratchet rhythm.

Chondromalacia has been considered by many to be simply a manifestation of hypertrophic arthritis; but its very isolated location in the joint, its frequency in young people, and the absence of arthritic changes in other articulations, point rather to a traumatic origin with secondary mechanical irritation of the joint. It is possible, of course, that this condition initiates what in older patients presents itself as a degenerative patellofemoral arthritis.

TREATMENT

In early cases, the treatment of traumatic degeneration of the articular cartilage of the patella should consist of protection of the joint from further trauma, and of the use of physical therapy, the basis of which should be mainly development of the extensor mechanism by active exercises with and without resistance. Many patients present little disability, if the area involved is small and the lesion quiescent, and if the patella glides within its normal depression in the intercondylar area. Once the symptoms have become chronically disabling, however, only radical surgical procedures can bring relief, and the following operations have been suggested for the cure of this condition:

1. Resection of the abnormal cartilage;
2. Total resection of the articular surface;
3. Patellectomy.

When the pathological changes are very limited in size and degree, the cartilaginous irregularities can be trimmed and smoothed down by careful dissection with a sharp knife, and the irregular borders of the craters can be beveled. This débridement has some value, and should be a routine procedure in the smaller lesions. But when the cartilage degeneration is more widespread, the problem is more difficult. Total resection of the articular cartilage, although recommended, has been done only once by this author, and then without relief of symptoms, a patellectomy being necessary at a later date; nor did two other patients, on whom the same operation was performed by other surgeons, show any improvement.

In those patients presenting extensive degeneration with incapacitating symptoms,

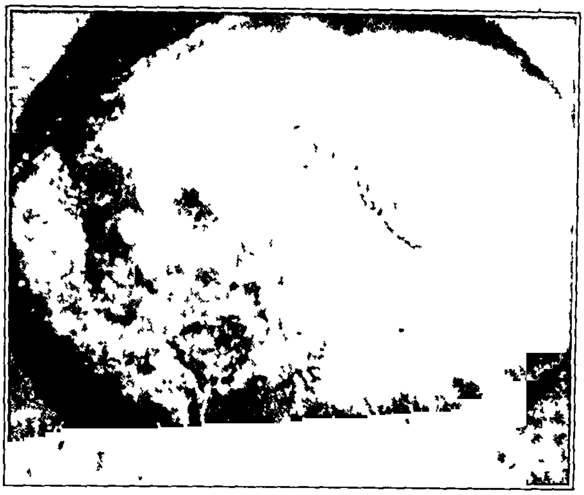

FIG. 3

Case 2. Lesion produced by instability of the patella.

FIG. 4

Case 3. Specimen from patient, aged twenty-seven, showing well-advanced fissures and tuft formations.

FIG. 5

Case 4. Specimen from patient, aged thirty-six. Advanced changes, showing fairly large area of exposed subchondral bone, are evident. This man presented a large "mirror image" in the intercondylar area of the femoral articular cartilage.

total excision of the patella should be considered. We have removed the patella in six such cases; all six of the patients had been prevented from performing their regular duties by the condition of their knees before the operation. Two of these obtained excellent function; two showed marked improvement and the results could be considered good, with a reduction of pain and absence of annoying crepitation. The last case is too recent for evaluation. One result could be classed as poor, presenting no improvement in function; this patient had a history of symptoms in the affected knee, extending over a period of ten years, and the femoral condyle presented a well-advanced "mirror image". The prognosis appears less favorable in cases showing involvement of the femoral condyle, a factor which should be kept in mind in considering early intervention.

Among technical considerations in patellectomy, certain points should be mentioned, as failure to observe them can lead to a residual derangement in function. We have approached the patella in later cases by a cup-shaped incision. The quadriceps expansion is incised in the same manner, so that the incision passes over the level of the inferior third of the kneecap. This tends to bring the suture line of the tendon in the area of the fat pad, rather than in the line of the femoral condyles. The quadriceps tendon is carefully removed from the patella by a meticulous sharp dissection. This results in an actual lengthening of the tendon, which should be corrected if the essential requirements of proper tension in any tenoplastic operation are fulfilled. This correction is made by overlapping the tendon about one-half inch (1.25 centimeters), so that proper tension is maintained; when this has been done, complete active extension will be regained more rapidly following the operation. By extending the medial arm of the incision somewhat higher and removing a V-shaped section, balance between the vastus lateralis and vastus medialis can be restored. This last step in the procedure should be reserved for those cases in which instability of the patella has been demonstrated.

It is of considerable importance that good muscle control should be taught the patient

by careful instruction *before* operation; and gentle quadriceps contractions should be resumed three or four days after the operation. Two weeks after the institution of active movements, a resistive exercise should be introduced, in order to develop the quadriceps. The resistance in the last 15 to 20 degrees of extension is particularly important, as this develops the vastus internus. All patients in this series regained normal extension by following this routine.

DISCUSSION

The clinical picture of chondromalacia with imbalance of the patella is often puzzling and deceptive, simulating other internal derangements of the knee. Because of this, in all knee arthrotomies it is obligatory that, through an adequate incision, a routine inspection of the joint be carried out; and this should include correct visualization of the cartilage of the patella, which can only be done while the knee is in extension, because in this position the quadriceps tendon is relaxed, allowing free mobility of the patella. The tension of the tendon during flexion is a serious objection to performing an arthrotomy through its entirety, with the knee in the flexed position, commonly used for excision of the menisci.

The impression should not be obtained that patellectomy is recommended in a large number of cases. Only those in which an extensive destructive and progressive lesion can be clinically demonstrated should be considered for this operation. In each case conservative methods of treatment must be given a thorough trial, before any radical measures are advocated.

Traumatic degeneration of the articular cartilage of the patella is of considerable clinical importance. It may result from nutritional impairment, following such common injuries as severe contusions, sprains, or fractures, or it may be produced by chronic traumatization, resulting from abnormal mechanics in the patellofemoral joint.

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PNEUMARTHROGRAMS OF THE KNEE

A Diagnostic Aid in Internal Derangements *

BY LIEUTENANT COLONEL W. H. MCGAW AND CAPTAIN E. C. WECKESSER

Medical Corps, Army of the United States

The rugged strain of jungle combat, beach landings, marches of twenty to thirty miles obstacle-course and unarmed training, produces a high incidence of the acute injuries of the knee joint, seen in our General Hospital. In addition, many remote "football" and "trick" knees that had been quiescent in civilian life soon become disabling under conditions of combat, with recurrent episodes of pain, effusion, and locking of varying severity. The history and clinical signs in many of these cases, though usually sufficient to make a diagnosis, are all too frequently not clear-cut, and, on occasion, are frankly misleading.

Schaer has estimated the incidence of errors in knee-joint diagnoses in his clinic as 15 per cent., and the authors regard this as conservative. In an attempt to evaluate our clinical errors in 101 cases requiring operation, we have classed or graded the preoperative diagnoses made by all our ward officers as follows:

Class A.	Entirely correct	37 per cent.
Class B.	Partially correct	42 per cent.
Class C.	Misleading	21 per cent.

In an effort to raise our percentage of correct diagnoses in borderline cases, we undertook the development of a technique for the roentgenographic visualization of the complicated intra-articular structures of the knee joint, since ordinary roentgenograms furnish little significant information.

To study the effect of a soluble radiopaque contrast medium, six fresh postmortem knee joints, prior to roentgenography, were filled with solutions of sodium iodide, varying in concentration from .25 to 8 per cent. The results were uniformly disappointing, as bone detail was obscured, and outlines of the menisci were indistinct.

Radiolucent contrast media proved much more satisfactory. The results with oxygen and the technique to be described have been especially gratifying. We consider oxygen ideal because of its availability, non-irritating quality, and fairly rapid absorption from the joint space. On a busy Service it has been a time-saving procedure to allow the oxygen to become absorbed from the joint during forty-eight hours of enforced bed rest following pneumo-arthrography. If the gas is to be aspirated following the x-ray examination, air, which is absorbed more slowly, serves just as well. Australian surgeons have used oxygen and carbon-dioxide mixtures with equal success.

Inflation of the knee joint with gas prior to roentgenography has been reported by a number of authors, as pointed out by Quaintance. One of us (W.H.M.) had the privilege of hearing a paper by Evans, who suggested that the knee joint be spread before taking roentgenograms. The modification and combination of these methods, together with helpful suggestions from many sources, have aided in the development of a technique which has yielded gratifying results in supplying diagnostic information not previously obtainable.

While, in 508 pneumarthrograms of the knee, no serious complications have been observed, we wish to call attention to the fact that fatal air emboli have been reported, following air injection in urological cases. Rettig, from a survey of the literature, reports four fatal cases in bladder injections. The fatalities were thought to be due to amounts of air in excess of ninety cubic centimeters. The same author also reports one case (described

* Read at the meeting of American and Australian Surgeons, Brisbane, Australia, December 12, 1943.

by Goldenberg) in which pneumopyelography was fatal, but quotes several other authors who report no fatalities or serious complications.

We have had no serious complications. One patient became faint for a short while upon sitting up, after the roentgenograms had been taken. Subcutaneous emphysema is occasionally seen, but has been without clinical significance. We have been very careful not to inject oxygen into the knee joint under forced pressure.

TECHNIQUE

To obtain roentgenograms that are worthy of interpretation, great care must be taken at each step. Hearty cooperation between the roentgenologist and the surgeon prevents disappointments, which were so common when ordinary methods were used.

Step 1. Inflation of the Joint

This is done with 1 per cent. procaine infiltration under strict aseptic precautions in the operating room (Fig. 1). A 20-gauge or 22-gauge needle is inserted into the lateral infrapatellar joint space. This is easily accomplished in the presence of increased synovial fluid, which should be carefully aspirated. In the absence of effusion, entry is facilitated by strongly displacing the patella laterally with one hand, while the needle is inserted into the sulcus formed between the patella and the lateral condyle of the femur (Fig. 2). Extrasynovial injection is carefully avoided, as it may impair or ruin the value of the procedure. When necessary, it is done by carefully directing the needle under the patella instead of into the loose fatty areolar tissue in the floor of the suprapatellar pouch, and by testing the free passage of gas back and forth through the needle and syringe. The joint is then *gently* distended with oxygen to the limit of comfort, usually requiring from 80 to 120 cubic centimeters. After the needle has been removed, a finger is kept pressed to the puncture wound for a few seconds after inflation, and the skin is then sealed with collodion.

One point of diagnostic significance can be elicited during the inflation of the joint. As intra-articular pressure increases, it reproduces the pain of any recent capsular or ligamentous sprain which is well localized to the particular structure damaged; but this pressure has no localized painful effect on a meniscal lesion or any other internal derangement.

Step 2. Localizing the Joint Space

The surgeon should mark the joint space accurately on the skin with ink or pencil, so that it can be seen in the positions of both the postero-anterior and anteroposterior roentgenograms. Some technicians are in the habit of centering the tube over the middle

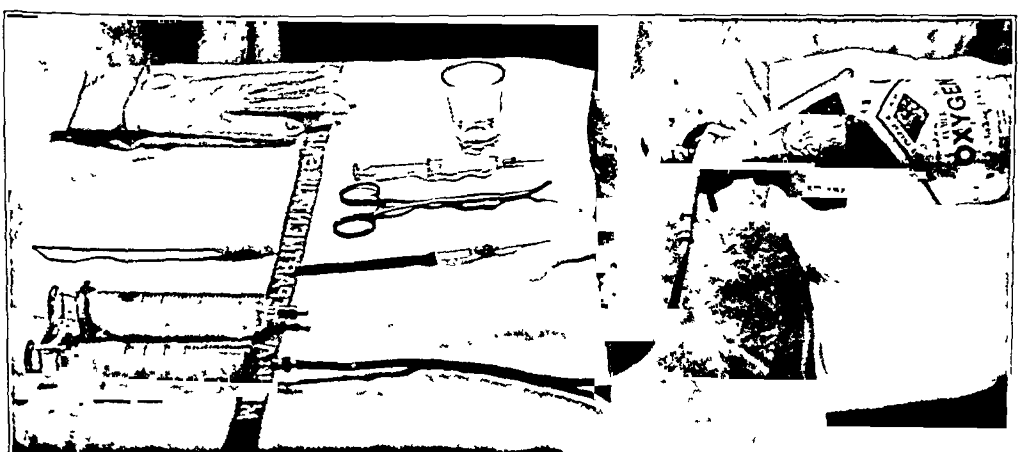

Fig. 1
Equipment for pneumarthrogram.

of the patella. This does not give a satisfactory profile view of the menisci or of the joint space. If there is an overlap of the femoral and tibial condyles on the plate, the meniscal shadow may be difficult to follow, and the view should be retaken. There is a slight individual variation in the plane of the tibial plateau which may require recentering of the x-ray tube by a careful technician, if the angle of the rays is not satisfactory.

After the skin has been marked, the patient is placed in the *prone* position on a cart, before being taken to the x-ray room. This position and pressure on the suprapatellar pouch encourage the spread of the gas throughout the joint, and allow the fluid, if any, to gravitate into the suprapatellar pouch.

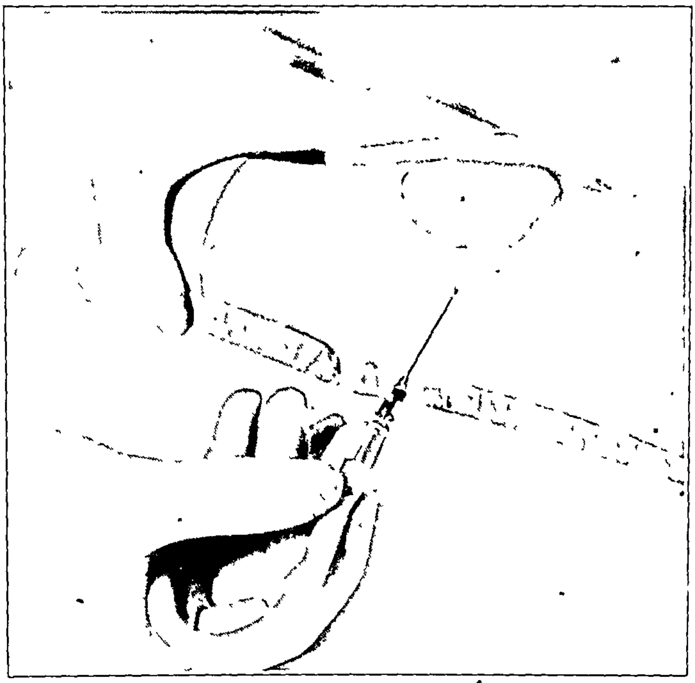

FIG. 2
Needle being inserted into sulcus between patella and lateral condyle of femur.

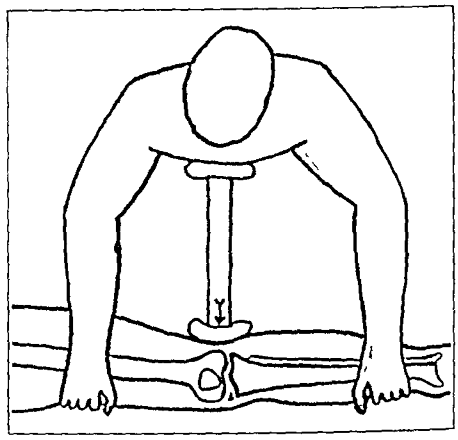

FIG. 3
Spread of medial joint space.

Although Cullen and Chance advise localizing the joint space fluoroscopically, we have not found this necessary as a routine procedure.

Step 3. Spreading the Joint Space

This is the most important step in taking satisfactory pneumarthrograms; and, if it is not carried out carefully, the value of the whole procedure is greatly reduced. The method is shown in the diagram (Fig. 3) of the technician and patient during the exposure of the x-ray film. The technician, properly protected, should sit on a low stool with a padded wooden bar held between his chest and the patient's knee joint. A lead arrow marker and sponge rubber are fixed to the knee end of the bar to show where the pressure has been applied. The technician exerts counterpressure through both hands, one around the ankle and one around the upper thigh. The opposite side of the knee joint is then levered apart by a steady, even, but strong pressure with the bar, and a simultaneous pull with his arms. After ten to fifteen seconds, the patient relaxes sufficiently to allow proper spreading. Then, at a signal, the exposure is made by another technician who has centered the tube accurately.

A mechanical device for spreading the joint can readily be constructed, as suggested by West. It consists of a bar with wide straps at either end to go around the thigh and the ankle, and a screw clamp through its center to apply pressure to the joint. We have found this to be of great value when we have had to use a portable x-ray unit. These two methods have been more satisfactory in our experience, than that recently mentioned by Somerville, in which the x-ray tube is pointed in a vertical direction, necessitating turning the patient on his side to take the anteroposterior or postero-anterior view.

Step 4. Roentgenographic Technique

The exposures are made with a fine-focus (two-millimeter) tube fitted with a cylin-

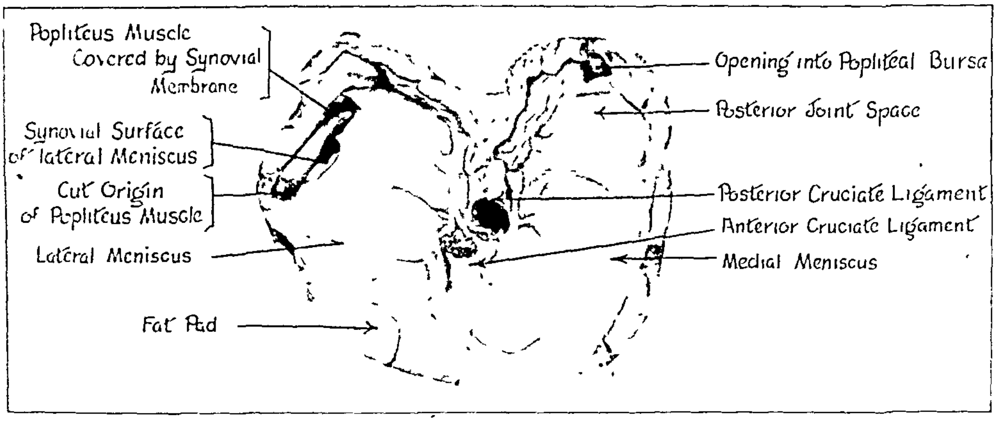

Fig. 4
Dissection of knee with femur removed.

drical cone, eight centimeters in diameter. The technical factors are as follows: a distance of thirty-six inches, average of fifty-five kilovolts, thirty milliamperes, and exposure of two-tenths of a second, with a par speed screen.

Five plates are taken as follows:

1. Postero-anterior view with spread of the medial joint space;
2. Postero-anterior view with spread of the lateral joint space;
3. Lateral view with the knee slightly flexed;
4. Anteroposterior view with spread of the medial joint space;
5. Anteroposterior view with spread of the lateral joint space.

The first three plates are usually the most valuable. In addition, oblique views may be taken, as suggested by Cullen and Chance, but it should be remembered that the anterior and posterior tips of the menisci cannot often be visualized, as their attachments are obscured by the tibial spines. However, it is unusual to encounter fractures of the menisci which are not visualized in these five routine views. Most tears of the cornua of the menisci will show some distortion of the center of the semicircle, which is routinely thrown into profile.

To obtain uniform results the knee is held in slight internal rotation for spread of the medial joint space, and in slight external rotation for spread of the lateral joint space. This is reversed, if a lesion of the posterior portion of a meniscus is suspected.

The oxygen may be allowed to escape through a needle reinserted into the procaine wheal; then the patient's activities are not restricted. Our usual practice, however, is to keep the patient in bed for forty-eight hours during which time most of the oxygen is absorbed. No postinflation medication has been required in any case. During pneumo-arthrog-

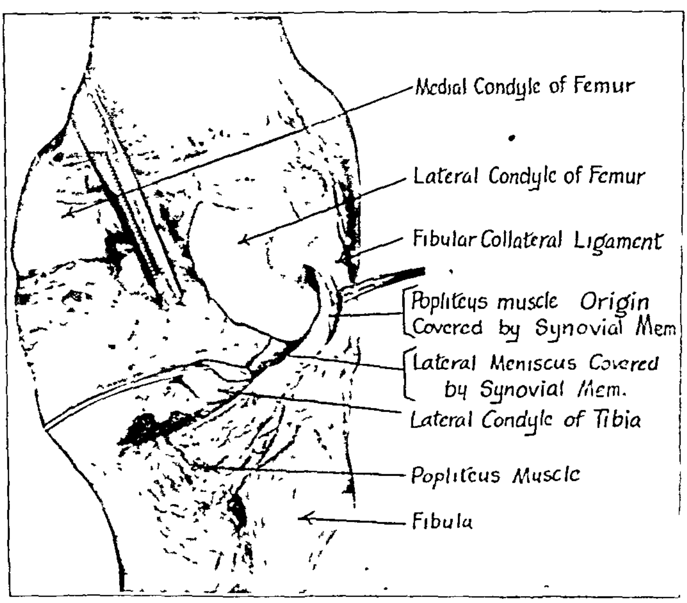

Fig. 5
Posterolateral dissection of the knee.

raphy on his own knee, one of the authors (W.H.M.) experienced a mild sensation of warmth in the knee for a few hours following the procedure.

ANATOMY

The anatomical attachments of the medial meniscus are so complete and simple that any abnormality in the pneumarthrograms of the medial side is a reliable indication of a lesion.

The lateral joint space with the popliteus muscle and the free portion of the lateral meniscus presents a much more difficult problem, and a correct interpretation of the confusing shadows demands an understanding of the variable anatomical relationships. Four fresh postmortem knee joints were dissected, and particular attention was directed to the attachments of the lateral meniscus and its relationship to the popliteus muscle and synovial folds (Fig. 4).

The popliteus muscle originates from a groove in the lateral epicondyle of the femur, just beneath the femoral attachment of the fibular collateral ligament (Fig. 5). This portion of its origin may be completely intra-articular, if the bursa between it and the collateral ligament communicates with the joint. As the tendinous origin of the muscle courses down obliquely across the posterior joint space, its outer edge is more or less fused with the posterolateral capsule of the knee. Its inner aspect, however, forms a distinct ridge covered by synovial membrane, and, as it passes downward, backward, and medially, lies in a groove in the upper edge of the tibial condyle.

The lateral meniscus has no peripheral capsular attachment where the popliteus muscle crosses it, and here the base of the meniscus is covered with synovial membrane. This explains the frequent vertical and normal oblique shadows in the lateral joint space in the pneumarthrograms, which, if seen on the medial side, would represent tears of the meniscal attachment.

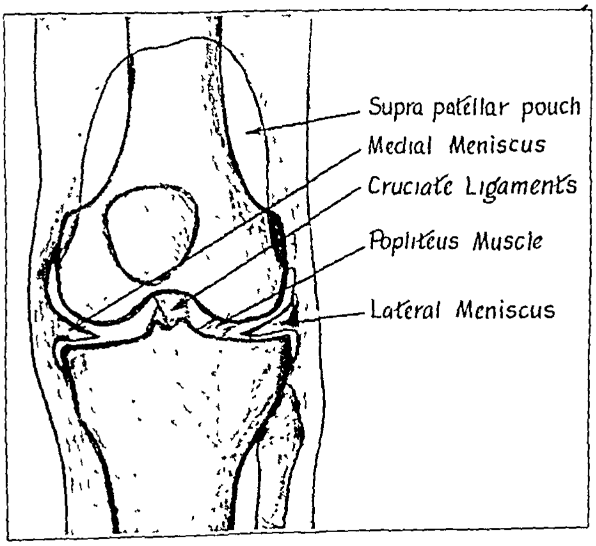

FIG. 6
Diagram of postero-anterior pneumarthrogram.

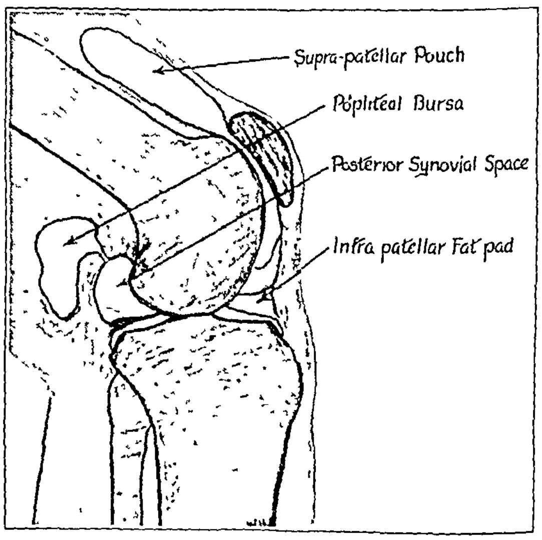

FIG. 7
Diagram of lateral pneumarthrogram.

INTERPRETATION

The diagrams in Figures 6 and 7 represent the anatomical structures which can be visualized in the pneumarthrograms. The edges of the normal menisci should be smooth and come to a sharp point. These details can be obscured by fluid and bubble formation, which is rare in our series of cases, or by an overlap of shadows of the tibial and femoral condyles.

The following outline lists briefly the types of abnormalities that may be recognized in an acceptable film.

The Menisci

Many fractures, tears, and dislocations are clearly shown by abnormal shadows, such as:

a. *Irregularity* in contour of either the femoral or tibial surfaces shows tears or shredding.
b. *Blunting or shortening* of the sharp edge indicates small tears or lesions of the cornu that distort the center of the meniscal shadow.
c. *Body or basal shadows* (in the absence of emphysema) show tears without displacement. These are of great significance in the medial meniscus, but much harder to interpret in the lateral meniscus.
d. *Partial or complete absence* of the meniscal shadow always indicates either a dislocation or a previous surgical removal.
e. *Abnormal sizes.* Meniscal shadows that are too long are "discoid". Those that are too broad are due to cystic changes of the menisci.

Synovial Cavities and Bursae

1. *Suprapatellar*
   a. A diminished capacity usually indicates previous inflammation or long immobilization. However, fibrous septa are normal and frequently found.
   b. Space-occupying lesions or non-calcified tumors are usually well outlined. However, small bodies are often not visualized.
2. *Infrapatellar*
   a. A diminished anterior joint capacity indicates the size of the fat pad, which may be larger than normal due to trauma, and may be the seat of hemorrhage, contusion or thickening, and fibrosis.
   b. The density of the tissue of the infrapatellar fat pad frequently suggests oedema or fibrosis, and may permit the diagnosis of hypertrophy.
   c. Abnormal contour of the fat-pad shadow is often suggestive of severe tearing and contusion. At times, rupture of the ligamentum mucosum can be recognized.
3. *The two posterior pouches:* We are too inexperienced to explain abnormal conditions here, although unusual shadows can be seen. We have suspected rupture of the popliteus muscle on occasion, but have never verified the suspicion.
4. *Popliteal bursae* communicate with the posterior pouches in 14.4 per cent. of our 508 pneumarthrograms. These are not considered to be of clinical significance, unless the history and physical findings point definitely to a Baker's cyst or popliteal bursitis.

Articular Surfaces

Patella: We have found that unusual sclerosis, slight irregularity, and cupping of the articular surface of the patella are associated with varying degrees of chondrosis, so that at operation we have noted roughening, softening, fibrillation, and shredding of the articular cartilage. These changes are frequently unrecognized causes of internal derangement of the knee.

The condyles of the femur and tibia: Chondrosis of these weight-bearing surfaces can be seen, if extensive, and it is associated with the usual signs of arthritis.

Osteochondritis dissecans is ordinarily recognized very readily in the pneumarthrograms, with a clearer indication of the extent of the lesion than in the plain roentgenogram.

Ligamentous Structures

The laxity of the collateral ligaments is indicated by the amount of separation of the femoral and tibial condyles, as seen on all postero-anterior and anteroposterior views. Some degree of lateral instability is a common finding in many of these cases.

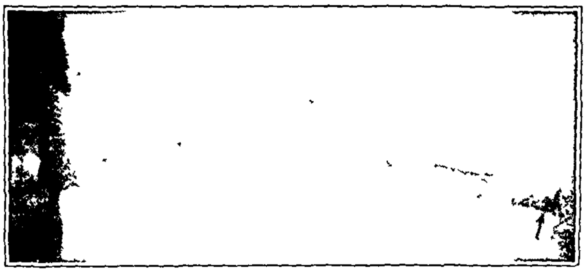

FIG. 8-A

Case 4772. Normal medial meniscus. With spread of the medial joint space, the shadow of the medial meniscus is thrown into distinct profile. This shadow appears as a smooth tapered wedge from its base or attachment to the capsular ligament. Note that both the superior (femoral) and inferior (tibial) surfaces of the meniscus are perfectly smooth, as they come to a point or sharp inner edge in profile. Compare with Fig. 6.

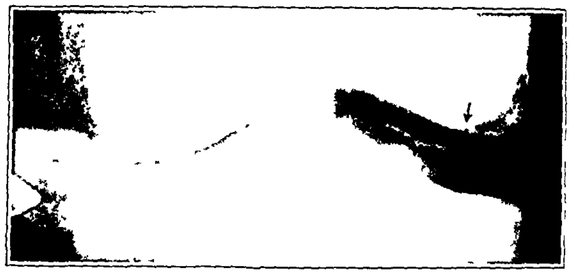

FIG. 8-B

Discoid meniscus. With spread of the lateral joint space, note the *extreme length* of the lateral meniscus which extends clear across the lateral joint space. The thinness of the meniscus in the center of the joint is indicated in this pneumarthrogram, but the tears are not visualized. The diagnosis of *discoid meniscus* could not have been made without this pneumarthrogram before operation. Compare with Figs. 6 and 9-A. This would be a normal-sized lateral meniscus if it only extended to the arrow, where the popliteus muscle shadow leaves the femoral condyle. Note the widening of the lateral joint space, indicating laxity of the lateral joint ligaments.

The shadows cast by the cruciate ligaments can at times be visualized on both the anteroposterior and lateral views, but ruptures cannot be diagnosed roentgenographically by this method.

During our first nine months' trial of this procedure, 207 cases were studied with pneumo-arthrography, and the number has now reached 508. Of the first 207 cases, 101 were operated upon, and an evaluation of their pneumarthrograms was verified by operation. The x-rays were reviewed without charts or names; then our diagnoses were checked with the operative findings, and an effort was made to grade their accuracy and value as follows:

Evaluation and check by operative findings in 101 cases:

A.	Conclusive diagnostic aid (irrespective of clinical findings)	43
B.	Limited diagnostic aid (confirming clinical findings)	40
C.	Misleading or contradictory aid (largely due to inexperience)	3
D.	Technically too poor and unsatisfactory for interpretation	15

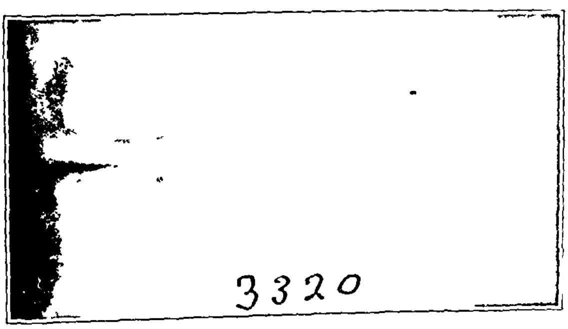

FIG. 9-A

Case 3320. Normal lateral meniscus. With spread of the lateral joint space, note the relatively thinner and longer shadow of the lateral meniscus in comparison with that shown for the medial meniscus in the previous case (Fig. 8-A). Note also that the body and surfaces of the meniscus are slightly irregular and distorted by the popliteus muscle shadow which runs down obliquely through it. This *does not* represent a tear. Note how the oxygen is squeezed out of the medial side of the joint.

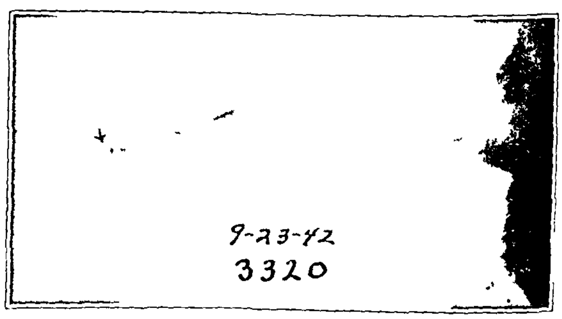

FIG. 9-B

Bucket-handle fracture-dislocation of the medial meniscus. With spread of the medial joint space, note the oblique blunted base of the medial meniscal shadow. Most of the body and inner tip of the meniscus is missing from its normal position. Compare with normal Fig. 8-A. Where a portion of the shadow of the meniscus is missing, there is always a dislocation, if the structure has not been removed surgically.

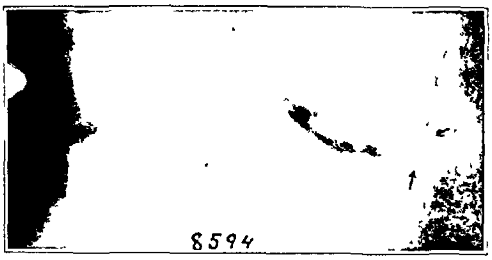

Fig. 10-A

Case 8594. Longitudinal tearing with partial dislocation of medial meniscus. With spread of the medial joint space, note the irregular shadow through the base of the ragged medial meniscus. Compare with the normal in Fig. 8-A. At operation the meniscus, which was split into two pieces with displacement of the posterior fragment, was excised. This case also had a lesion of the lateral meniscus. See Fig. 10-B.

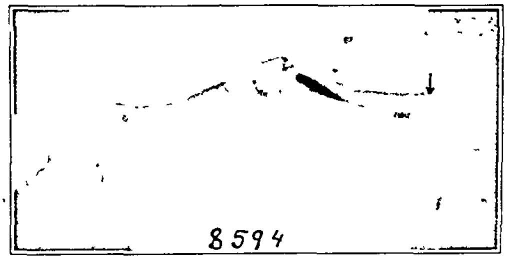

Fig. 10-B

Bucket-handle fracture of the lateral meniscus. With spread of the lateral joint space, note the absence of the tip of the lateral meniscus. This shows a definite dislocation. Note the blunted irregular portion of the base of the meniscus left attached. Compare with normal lateral in Fig. 9-A. It was excised at the same operation (Fig. 10-A). Because of the pneumarthrograms, the bilateral operation could be anticipated and planned.

We do not hesitate to eliminate films in *D* in arriving at a final diagnosis. Our ability to interpret pneumarthrograms has progressed steadily with experience and improvement in technique.

A few of the Army's overseas hospital units have made sporadic attempts at pneumo-arthrography in forward areas, but the pneumarthrograms obtained in many instances have been disappointing. Poor technique and limited facilities completely vitiated the value of this procedure. It is our opinion that pneumo-arthrography should not be attempted unless all x-ray facilities are of the best, and minute attention to all aspects of the technique is possible.

CLINICAL CASES WITH THEIR PNEUMARTHROGRAMS

Fewer than half of the patients represented by this series of 508 pneumarthrograms have come to surgery. Correct diagnosis, treatment, and proper Army disposition of the cases, whether or not operation was deemed necessary, have been materially enhanced by the information obtained by this procedure.

We are here presenting a series of cases illustrating a variety of the typical findings.

Case 4772. This man, aged twenty-three, was admitted January 14, 1943, with a complaint of constant swelling and aching, and inability to hike for the past three months. This condition had begun during island combat. Examination disclosed increased fluid in the joint, with limitation of extension of 10 degrees, and tenderness over the lateral joint space. Pneumarthrograms (Fig. 8-A) disclosed a perfectly normal medial meniscus, while the lateral meniscus was seen to extend clear across the lateral joint space (Fig. 8-B). We were thus able to make a preoperative diagnosis of a discoid meniscus. At operation on February 9, 1943, the diagnosis was verified, and the discoid excised. The central portion of the meniscus was torn and ruffled up. On March 29, 1943, the patient was transferred to another hospital for convalescence.

Without a pneumarthrogram we should not have been able to make an accurate preoperative diagnosis.

Case 3320. The patient, aged twenty-seven, was admitted September 12, 1942, complaining of pain, swelling, and clicking in the right knee. He stated

Fig. 11

Case 6017. Longitudinal tear without dislocation of the medial meniscus. With spread of the medial joint space, note the irregular oblique shadow of the tear through the base of the meniscus. The inner portion of the meniscus is distorted, but not displaced from the periphery of the joint. Compare with the normal (Fig. 8-A).

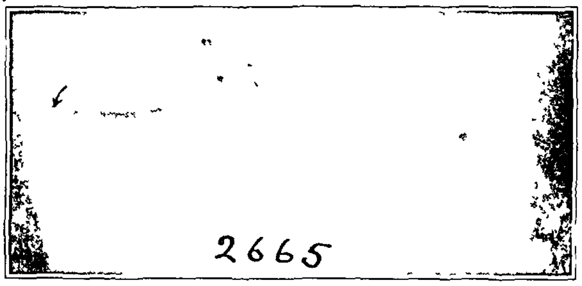

Fig. 12-A

Case 2665. Normal medial meniscus. With spread of the medial joint space, the medial meniscus is visualized as a normal structure, its superior and inferior surfaces are smooth, the shadows come to a good point, and it shows a normal wedge attached to the capsule. This pneumarthrogram has not been centered properly, because the femoral and tibial condylar shadows overlap.

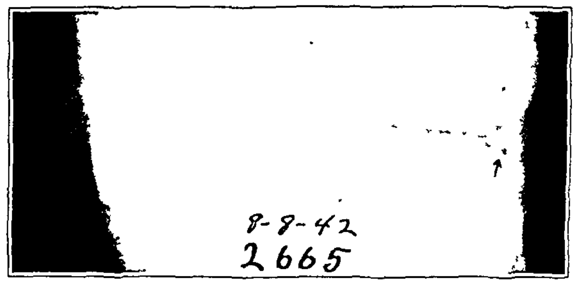

Fig. 12-B

Frayed lateral meniscus. With spread of the lateral joint space, note that the lateral meniscal shadow is extremely thin and its inferior surface is markedly irregular and blurred. Compare with the normal lateral (Fig. 9-A). Irregularity of the lateral femoral condyle is also suggested in this pneumarthrogram. Because of lack of confidence in recognizing this abnormal shadow, we were misled by the clinical signs on the medial side of the joint. The medial joint space was first opened at operation, but the proper diagnosis should have been made from this pneumarthrogram.

that he was first injured in April 1942, when he twisted and bumped his knee on the firing range. Examination disclosed a slight amount of increased fluid in the joint and tenderness over the anteromedial joint space. Figure 9-A shows a normal lateral meniscus in the pneumarthrograms, while Figure 9-B shows blunting of the medial meniscus and partial absence, which always indicates dislocation of that portion. At operation on October 16, 1942, a bucket-handle fracture of the medial meniscus was found, as well as mild chondrosis of the patella. The patient returned to duty on February 12, 1943.

Case 8594. This man, aged twenty-three, was admitted May 22, 1943, with a history of three severe attacks of locking since the original injury in May 1942. Examination disclosed slight hypermobility, a small amount of increased fluid in the joint, and tenderness over the anteromedial joint space. Following pneumo-arthrography (Figs. 10-A and 10-B), the complete diagnosis of tears of both the lateral and medial menisci was made, so that at operation on June 2, 1943, both menisci were excised through two small incisions. The patient made an excellent recovery, and was discharged to duty on July 8, 1943.

It would have been impossible to make the complete diagnosis in this case from the clinical findings alone. Therefore, another operation and much time were saved.

Case 6017. The patient, aged twenty-two, was admitted on August 8, 1943, with a history of frequent slipping and partial locking in the right knee since the original injury of falling and twisting his knee during field manoeuvres in February 1940. Examination disclosed a slight amount of increased fluid, moderate lateral hypermobility, and anteromedial joint tenderness. The pneumarthrograms (Fig. 11) confirmed the diagnosis in this case. The medial meniscus, which was found to be completely torn loose from its base and markedly shredded, was excised on August 11, 1943. The patient was transferred to another hospital for convalescence on October 5, 1943.

Case 2665. An officer, aged thirty-three, was admitted on August 6, 1942, with a complaint of swelling, clicking, and pain on weight-bearing in the left knee, following a fall during manoeuvres on July 10, 1942. Examination disclosed distinct point tenderness over the anteromedial aspect of the joint, with increased fluid, and occasional crepitus on motion. The patient was operated upon on August 11, 1942. Because of the localized tenderness, the medial joint space was opened first, in spite of the normal appearance of the medial meniscus in the pneumarthrograms (Fig. 12-A), although the lateral meniscus, as shown in Figure 12-B, appeared very thin and irregular. The medial meniscus was normal, and the lateral meniscus was torn and markedly frayed longitudinally, but not displaced. The lateral femoral condyle also showed softening and roughening of the articular cartilage. This is one of our early cases, and is presented, because the clinical signs were entirely misleading, although the pneumarthrograms indicated the true diagnosis.

An unnecessary incision would have been avoided with more confidence in the pneumarthrograms.

Case 5602. The patient, aged twenty-one, was admitted February 8, 1943, complaining of pain, weakness, and clicking in the left knee. Examination disclosed anteromedial joint tenderness with

crepitus and increased fluid in the joint. The pneumarthrograms (Fig. 13) disclosed an irregular tear of the medial meniscus, and the tibial half was dislocated as in a typical bucket-handle tear. The femoral surface of the meniscus appeared relatively smooth. The meniscus was excised on February 27, 1943, and the patient was returned to duty on April 28, 1943.

CASE 2922. This soldier, aged thirty-three, was admitted September 2, 1942. On August 23, 1942, while working in a kitchen, the patient had slipped on the wet floor, twisting the right knee. On admission he showed limitation of extension of 15 degrees, and anteromedial joint tenderness. The pneumarthrograms (Fig. 14) confirmed the clinical diagnosis of fracture-dislocation of the medial meniscus. This was found at operation on September 11, 1942. The patient was returned to duty on December 21, 1942.

When a portion of the meniscus is missing, as in this case, there is always a dislocation of the torn fragments.

CASE 1928. The patient, aged twenty-four, was admitted July 10, 1942, with a complaint of occasional slipping, catching, and swelling in the right knee, particularly after hiking. This knee was first injured in football in 1933, and examination disclosed pain, tenderness, and clicking in the anteromedial joint space, with a slight amount of fluid in the joint. The pneumarthrograms of the lateral view (Fig. 15) disclosed a markedly enlarged fat pad with a dense fibrotic tip. At operation the anterior cornu of the medial meniscus was torn loose from its attachment to the tibia, and the thickened fat pad with a hyalinized tip overhung this portion of the medial meniscus. The anterior cornu and the fat pad were excised on July 17, 1942. The patient was returned to limited duty on December 22, 1942, with added diagnoses of essential hypertension and moderately severe varicose veins.

CASE 770. The soldier, aged twenty-three, was admitted May 25, 1942, with a complaint of stiff knee and multiple bomb fragments sustained in a raid in February 1942. On admission there were multiple scars over the anterior and medial aspects of the knee, with a wide draining area just proximal and medial to the patella. On July 24, 1942, many bomb fragments were removed with areas of dense scar tissue, and the large scar was covered with a flap of skin. On January 13, 1943, other palpable fragments of foreign bodies were removed. On February 16, 1943, a partial arthroplasty of the knee was performed with excision of the patella. Many fibrous bands and adhesions were found throughout the joint. The quadriceps tendon was lengthened and the anterior joint was lined with a fascia lata graft. The patient obtained range of motion of almost 90 degrees, and was returned to the United States on April 12, 1943.

This case is presented to show the effect of foreign bodies and chronic infection in the joint space. We have found diminished joint capacity in all cases of infectious arthritis or synovitis.

CASE 5364. The patient, aged twenty-four, was admitted February 4, 1943, complaining of inability to march, due to recurrent pain and swelling in the right knee, which was first injured in football in 1938. He showed a slight amount of increased fluid, and tenderness over the lateral joint space. The

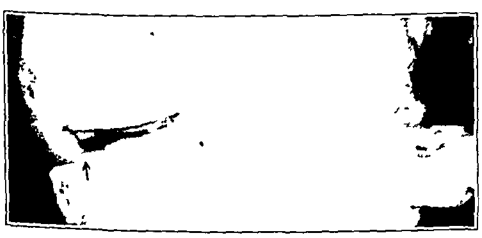

FIG. 13

Case 5602. Bucket-handle fracture-dislocation of medial meniscus. With spread of the medial joint space, note that the medial meniscus is only partially visualized. A portion of the tip and tibial surface of the meniscus is displaced into the center of the joint, leaving the small irregular fringe of the medial meniscus attached to the base. Where a part of the meniscus is found to be missing or blunted, one can always expect a dislocation of that portion of the meniscus.

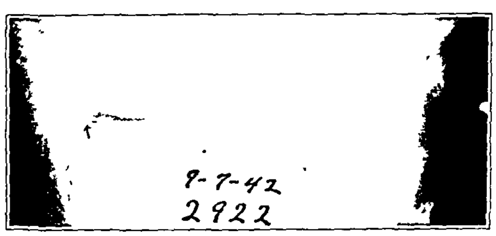

FIG 14

Case 2922. Bucket-handle fracture-dislocation of medial meniscus. With spread of the medial joint space, note the missing portion of the medial meniscus and the irregular area of the base remaining attached. At operation there was a bucket-handle fracture-dislocation involving about half of the width of the meniscus. Pneumarthrograms following surgical removal of a meniscus often have this appearance. Compare with the normal in Fig. 8-A.

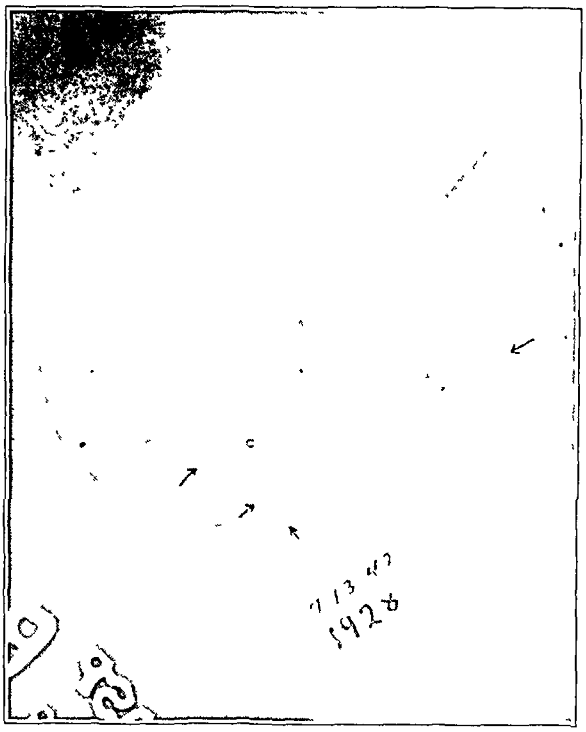

FIG. 15

Case 1928. Hypertrophied fat pad with fibrous tip. This lateral view shows greatly diminished oxygen in the anterior joint space between the patella and tibia, due to the hypertrophied infrapatellar fat pad. The fibrotic tip of the lower edge of the fat pad is clearly visualized.

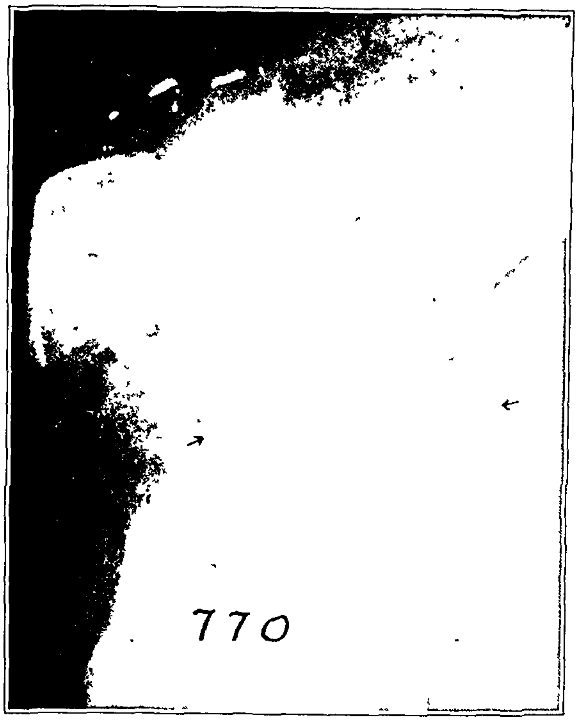

FIG. 16

Case 770. Diminished joint space, due to infection and foreign-body reaction in and around the knee joint. This lateral pneumarthrogram, made five months following injury sustained in a bombing raid, shows the marked diminution of the joint space which held only fifteen cubic centimeters of oxygen. At operation marked fibrosis and partial fibrous ankylosis, particularly around the medial condyle of the femur and patella were found. Compare with Fig. 7.

pneumarthrograms confirmed the diagnosis of a torn lateral meniscus. This was excised on February 13, 1943. At operation the posterior cornu was found to be folded back on itself, though this is not shown in the pneumarthrograms (Fig. 17). The patient was returned to duty on April 6, 1943.

CASE 5031. The soldier, aged twenty-two, was admitted on January 13, 1943, with a complaint of pain, swelling, and occasional clicking in the right knee, following an injury sustained when he jumped off a moving truck three weeks before. Pneumarthrograms (Fig. 18) confirmed the diagnosis of a torn lateral meniscus, which was removed on February 1, 1943. The patient was returned to duty on April 15, 1943.

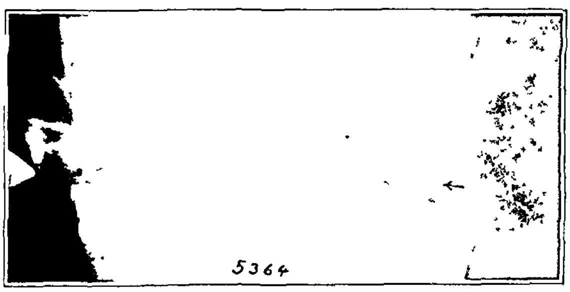

FIG. 17

Case 5364. Longitudinal and posterior tear of the lateral meniscus. With spread of the lateral joint space, note the irregular longitudinal tear on the inferior or tibial surface of the lateral meniscus. Compare with the normal lateral (Fig. 9-A). Some of these tears may be missed at operation if only the superior femoral surface of the meniscus is inspected.

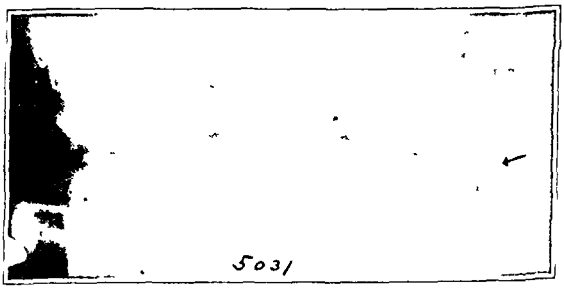

FIG. 18

Case 5031. Longitudinal tear of the lateral meniscus. With spread of the lateral joint space, note the irregular longitudinal tear through the center of the lateral meniscus, which extends almost to its base. At operation, this tear was found and the meniscus was removed. Compare with the normal lateral (Fig. 9-A).

If pneumarthrograms had not been taken, this early case would have been treated conservatively until the patient had had recurrent episodes. The clinical diagnosis was sprain with possible tear of the lateral meniscus.

Case 1661. The patient, aged twenty-eight, was admitted June 30, 1942, complaining of pain, aching, and swelling of the left knee, and inability to march and hike. There was no recent history of injury in this case, although the patient thought he had been struck by a baseball in infancy. Examination disclosed a tender swollen mass on the lateral aspect of the knee joint. A clinical diagnosis of a cyst of the lateral meniscus was made. A plain roentgenogram (Fig. 19-A) was reported negative, although after clinical examination a spread of the lateral joint space could be seen. The pneumarthrograms (Fig. 19-B) in this case show the interesting contrast between the ordinary film and the pneumarthrograms, which show a normal medial meniscus and on the lateral side a huge meniscus, which

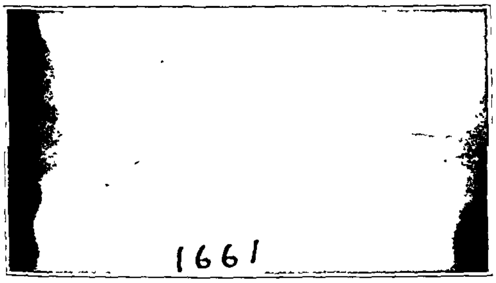

Fig. 19-A

Case 1661. Plain roentgenogram. This film was reported negative. However, soft-tissue bulging and widening of the lateral joint space can be detected on careful study. We are presenting this film to show the marked absence of detail of intra-articular structure from that obtained in the pneumarthrogram.

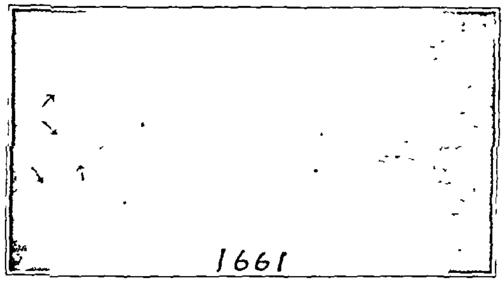

Fig. 19-B

Cyst of the lateral meniscus. When compared with the ordinary roentgenogram, it can now be seen that the lateral meniscus almost completely fills the lateral joint space, and displaces the joint capsule laterally. Note the extremely broad base of the meniscus bulging into the synovial cavity, both above and below, and the areas of decreased density in the meniscus, representing the multilocular cyst. The shadow of the medial meniscus appears normal. Compare with the normal (Figs. 6 and 9-A).

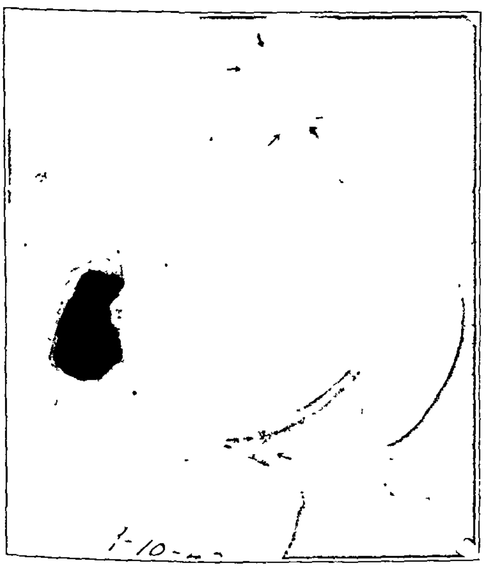

Fig. 20-A

Case 1450. Synovioma in suprapatellar pouch. This lateral view discloses the size, shape, position, and attachment of the synovial tumor in the suprapatellar pouch. This tumor is not visualized in the ordinary roentgenogram. Note the increased density of the fat pad in this pneumarthrogram. This may represent thickened synovia due to recurrent synovitis with effusion.

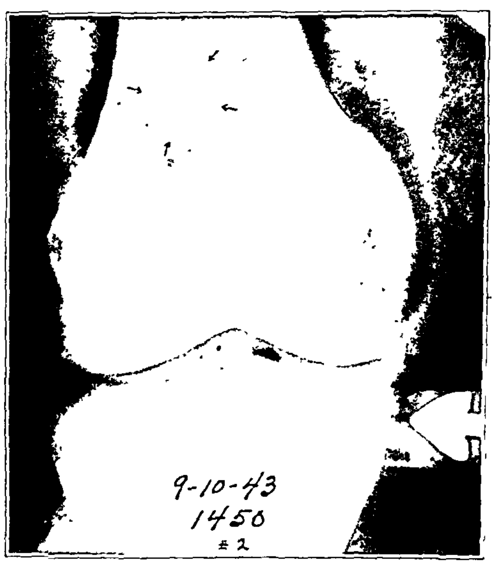

Fig. 20-B

This anterior view shows the rounded solid tumor, well encapsulated, situated just proximal to the patella in the suprapatellar pouch.

almost completely fills the joint space and bulges into the synovial pouch both above and below its base. The areas of decreased density in the meniscus, representing the multilocular cyst, are also visible.

CASE 1450. The soldier, aged twenty-one, was admitted September 3, 1943, with a complaint of recurrent swelling in the right knee which had begun about three years before without trauma. Examination disclosed increased fluid in the joint and a palpable mass in the suprapatellar pouch, which was attached to the floor of the bursa. The lateral and anteroposterior pneumarthrograms (Figs. 20-A and 20-B) outlined this tumor mass which did not show on the ordinary roentgenograms. A benign synovioma, which was pedunculated and well encapsulated, was excised on September 17, 1943. On November 5, 1943, the patient was returned to duty.

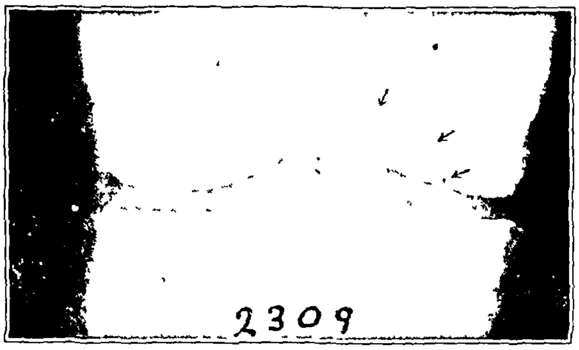

FIG. 21

Case 2309. Osteochondritis dissecans. Note how well the oxygen outlines the sémi-detached fragment of bone and cartilage in the medial condyle of the femur. In the plain anteroposterior roentgenogram, this defect can be detected on close inspection. There is too much fluid in this knee to allow proper visualization of the menisci.

CASE 2309. The patient, aged twenty-three, was admitted July 22, 1942, with a complaint of pain, swelling, and grating in the left knee. The soldier stated that his knee was first injured when he fell from a bicycle in 1935. Examination disclosed increased fluid with medial-joint tenderness and occasional crepitus. The pneumarthrograms (Fig. 21) clearly showed osteochondritis dissecans, and the semi-detached portion was excised on July 28, 1942. *This defect showed on the ordinary roentgenograms,* particularly on the lateral view, but could have been missed on the anteroposterior view. The patient was returned to duty on December 23, 1942.

Fractures of the patella can also be well visualized on the anteroposterior view with pneumo-arthrography.

SUMMARY

1. A satisfactory procedure for oxygen pneumo-arthrography is presented which has been used in 508 examinations of the knee.
2. The four steps in the procedure are outlined.
3. The complicated anatomy of the lateral meniscus is emphasized and demonstrated by Figures 4 and 5.
4. The difficult interpretation of the various shadows involving the lateral meniscus is discussed.
5. A general outline for interpretation of pneumo-arthrographic findings is presented.
6. Fourteen cases in which operations were performed are described to show a variety of lesions in which the pneumarthrograms have been of value.
7. A plea is made for the necessity of perfect technique in this procedure to prevent disappointing results.

CONCLUSIONS

1. Pneumarthrograms have been made of 508 knees with only negligible local reactions and no serious complications.
2. The roentgenographic diagnosis of many internal derangements of the knee may be possible in the following types:
   a. Many lesions and anomalies of the medial and lateral menisci;
   b. Cysts of the popliteal space which communicate with the knee joint;
   c. A few lesions of the infrapatellar fat pad;
   d. Some soft-tissue tumors of the synovial membrane;
   e. Some large loose bodies;
   f. Relaxation of the collateral ligaments.
3. The procedure described has in many cases facilitated an early and complete diagnosis, which has hastened appropriate therapy and a quicker return to active duty.

4. Oxygen pneumo-arthrography has materially assisted the Army in the proper disposition of cases.

We wish to express our indebtedness to the many who have made this study possible, and in particular to the following:

Colonel W. C. McCally, Lieutenant Colonel D. M. Glover, and the whole Surgical Service of the Fourth General Hospital for their aid.

Lieutenant Colonel E. Freedman and the whole X-Ray Department for their support and cooperation.

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LATERAL DISLOCATION OF THE PATELLA

Correction by Simultaneous Transplantation of the Tibial Tubercle and Semitendinosus Tendon

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Persistent or recurrent lateral dislocation of the patella may be either congenital or acquired. The congenital variety includes dislocations resulting from relaxation of the sôft tissues about the joint (Fig. 1), from the flat or sloping anterior surface of the lateral femoral condyle, from an occasional congenital knock-knee (Fig. 2), or from the rare instances of maldevelopment of the extensor mechanism of the knee. In this latter type, the quadriceps femoris muscle itself may be present, but atrophied and weak from disuse. The patella may be abnormally placed in the quadriceps tendon or displaced far to the side, and the patellar tendon may be inserted on the lateral aspect of the tibia. In some instances, there appears to be complete absence of the vastus medialis portion of the quadriceps femoris muscle.

The acquired type of dislocation may result from one or more traumatic dislocations in which there is a tear and subsequent faulty repair of the soft-tissue structures on the medial aspect of the knee, or from an acquired knock-knee deformity. Frequently dislocation is produced by the abnormal pull of a biceps femoris tendon which had been previously transplanted to the patella in an attempt to replace a paralyzed quadriceps muscle in poliomyelitis. Several years ago, transplantation into the patella of the biceps femoris tendon alone was a commonly practised procedure in attempting to provide a substitute for a paralyzed quadriceps mechanism. Adequate follow-up over a period of several years revealed that many of these patients developed a lateral subluxation of the patella from

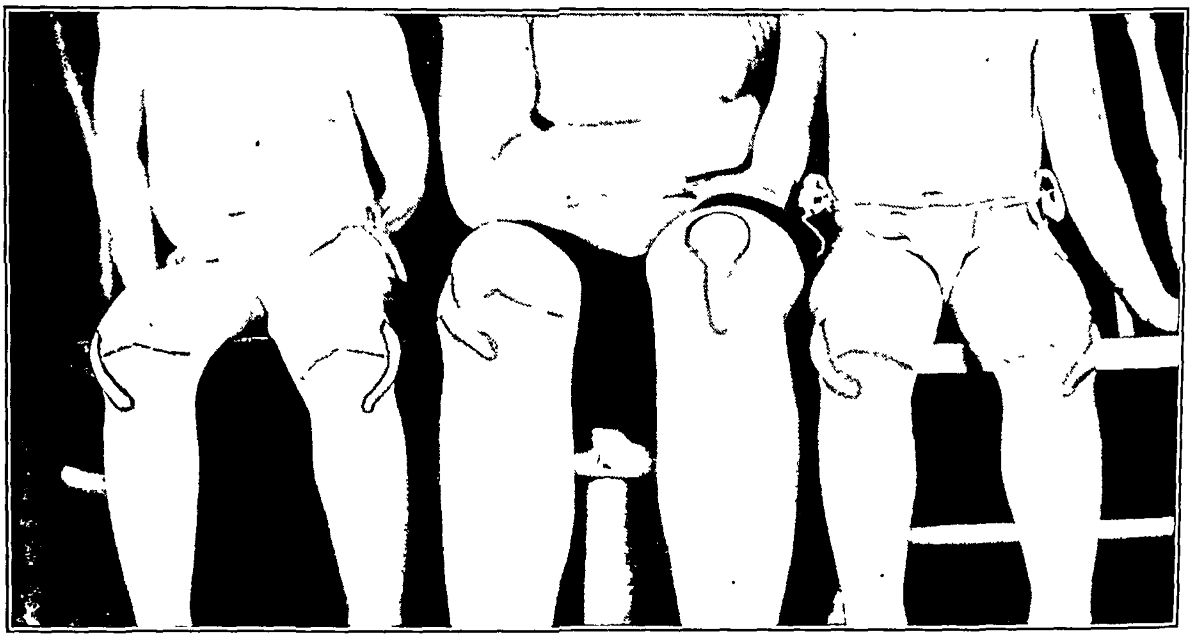

Fig. 1

Mother with unilateral congenital dislocation of the patella, and two children, aged six years and four years, with bilateral dislocations of similar type. These were due apparently to congenital relaxation of soft-tissue structures on the medial aspect of the joint. The two children, although operated upon, are not included in this report because of insufficient time elapsed since the operation.

the unbalanced pull of the transplanted tendon. This was the factor primarily responsible for the institution of the double hamstring transplant,—namely, simultaneous transplantation of the biceps femoris and the semitendinosus tendons in order to produce a balanced pull on the patella from both the medial and lateral aspects.

Many operative procedures, sixty according to one report, have been described for correction of persistent dislocation of the patella. These have been adequately reviewed by Campbell and by Hauser so that repetition seems unnecessary here. Likewise, no attempt will be made to discuss the merits of the various procedures. Each will undoubtedly give satisfactory results in many instances, but none can be fully depended upon to afford permanent satisfactory correction in all cases.

In this series of forty-three dislocating patellae, most of which have received treatment at the St. Louis Unit of the Shriners' Hospitals for Crippled Children, thirty are classified as congenital in origin, and thirteen as acquired. Of the thirty congenital cases, twenty-five have been thought to result primarily from congenital relaxation of the soft tissues about the joint, four from a marked congenital knock-knee deformity, and one from maldevelopment of the quadriceps mechanism. Of the acquired type, eleven resulted from the transplantation of the biceps femoris tendon into the patella in an effort to replace a paralyzed muscle after an attack of poliomyelitis; one was thought to be due to repeated traumatic dislocations, and one resulted from an acquired knock-knee deformity.

FIG 2

Bilateral congenital dislocation of the patella, associated with or resulting from marked congenital knock-knee.

Four different operative procedures have been used in the treatment of these forty-three knees. In the few instances where knock-knee deformities were present, osteotomies and realignment of the extremity were performed in addition to other reconstructive procedures. Osteotomies, therefore, are not included in the following consideration. In one series of four knees, the lateral half of the patellar tendon was transplanted to the inner surface of the tibia according to the method of Goldthwait. Recurrent dislocations occurred in two of these knees during the first year after operation, and the results were classed as unsatisfactory. From a second series of five knees, in which the semitendinosus tendon was transplanted into the patella, four were satisfactory, while in one, dislocation recurred very soon after operation.

In a third series of eleven knees, the tibial tubercle [tuberosity of the tibia] alone was transplanted, medially and lower on the shaft of the tibia, similar to the procedure described by Hauser. This was the procedure most frequently used at the Shriners' Hospital between the years 1931 and 1935. Of the eleven cases, nine remained satisfactory, and recurrent dislocations followed in two of the knees within a short period of time. This represents a failure in 18 per cent. of the cases, not greatly different from the 10 per cent. of failures for the same procedure reported by Houkom. In one of our failures, the tibial tubercle was retransplanted at a second operation, but again the dislocation recurred; this was a case of poliomyelitis in which the dislocation was due to the pull of a transplanted biceps femoris tendon. The second failure, however, was in a case of congenital relaxa-

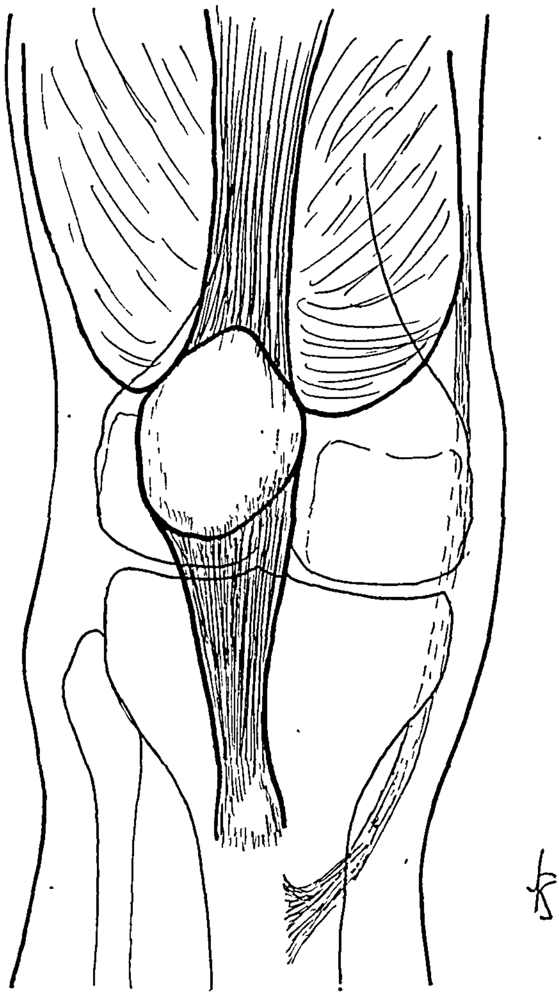

FIG. 3-A

Diagrammatic sketch of the knee, showing the usual relationships of the patella, patellar tendon, and tibial tubercle, with the knee extended in a congenital recurrent dislocation of the patella. Note that the patella lies over the lateral condyle, rather than in the groove between the two condyles. Also shown is the normal insertion for the tendon of the semitendinosus muscle.

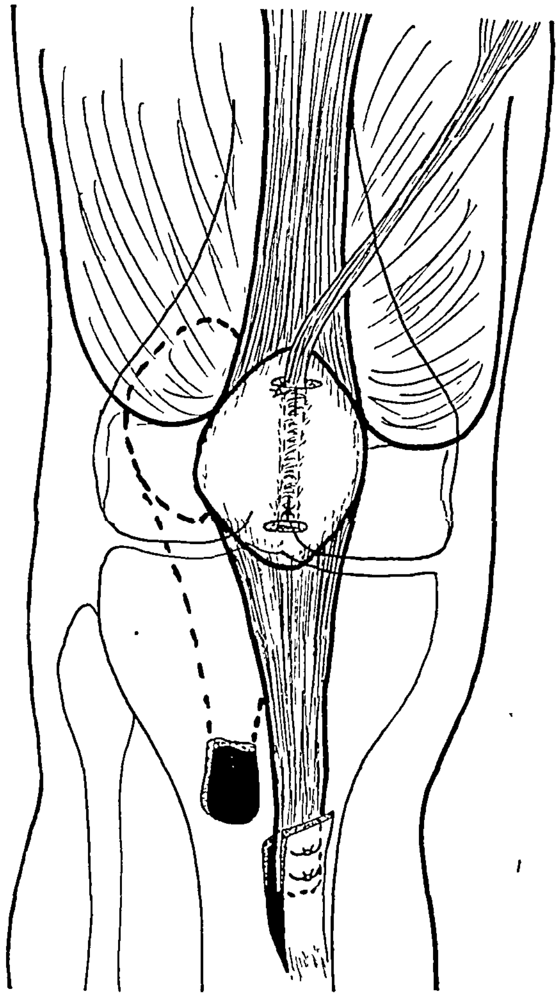

FIG. 3-B

Diagrammatic sketch, showing the same knee seen in Fig. 3-A, following operation. The tibial tubercle has been transplanted medially and inferiorly on the shaft of the tibia, and the insertion of the semitendinosus tendon has been transplanted into the patella. Note that the patella is now fixed in its normal mid-line resting position.

tion. Knock-knee deformity was not a factor in either case. The two failures for this operation in a series of eleven cases represent a percentage of unsatisfactory results too high to justify classification of the procedure as entirely satisfactory and acceptable. Transplantation of the tibial tubercle alone, therefore, has not been in use in this clinic since 1935. It has been supplanted by transplantation of the semitendinosus tendon into the patella at the same time that the tibial tubercle is transplanted. This procedure has been carried out in the remaining twenty-three knees. This is not claimed as an original procedure, because it is essentially a combination of the procedures of Hauser and Robertson, although the semitendinosus tendon is given a bony insertion into the patella. It is merely described as a relatively simple operation which has proved to be generally satisfactory. Once the patella has been shifted medially and firmly anchored to the medial aspect of the extremity from both above and below, it cannot redislocate into a lateral position. Since the procedure is usually extra-articular, there is a minimum of joint reaction and a maximum preservation of joint function.

OPERATIVE TECHNIQUE

A longitudinal mid-line incision is begun two inches (five centimeters) above the patella, and continued distally to the tibial tubercle. It is then curved medially and con-

tinued downward and medially beneath the medial tibial condyle for approximately two more inches. The skin flaps are reflected, and the broad expansion of the sartorius tendon is identified and opened in the line of its fibers. This exposes the insertions of the gracilis and semitendinosus tendons, the latter occupying the inferior position. The semitendinosus tendon is divided near its insertion, then freed from its other attachments to the adjacent tendons and ligamentous structures along the posteromedial aspect of the knee. A second incision, two inches in length, is made along the posteromedial surface of the thigh at about its mid-point. This point is made accessible by flexing the hip and knee, and permitting the hip to roll outward. By placing tension on the detached tendon below, the belly of the semitendinosus muscle can be easily felt and identified, lying along the posterior surface of the semimembranosus muscle. The overlying fascia is opened longitudinally, and the muscle belly is lifted out with the index finger. By traction, the tendon can then be pulled upward and brought out through this small incision. A larger incision is not necessary. A wider exposure only increases the amount of surrounding scar tissue, which may interfere with the gliding motion of the transplanted muscle and tendon.

By blunt dissection with scissors and a Kelly clamp, a tunnel is then made from the small upper incision, downward and forward through the subcutaneous tissue, to the upper limit of the original anterior incision. The tunnel is enlarged as needed at the proximal end in order to accommodate the muscle belly. The tendon is drawn through the tunnel and the small incision is closed.

The tibial tubercle is then detached. This can be done by placing a sharp thin osteotome directly back of the tendon, holding it parallel to the long axis of the leg, and removing only the superficial portion of the tubercle with the tendinous attachment. If the operation is being done in a growing child, which is frequently the case, care must be taken not to damage the underlying epiphyseal line of the tibia. Experience has shown that this procedure can be carried out without injury to the growth structure. A block of bone is never removed, and it is not necessary for the success of the procedure. The patellar tendon is then freed from the underlying fat pad, and the lateral fascia is opened from below upward, along the lateral margin of the vastus lateralis, sufficiently high to permit shifting the patella

Fig 4-A

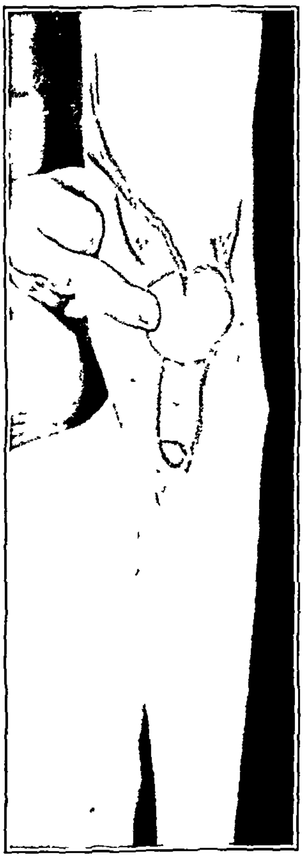

Fig 4-B

Fig 4-A Case 2 Congenital dislocation of the patella resulting from relaxation of the soft-tissue structures about the joint Note the ease with which the patella can be dislocated laterally from slight pressure exerted on the medial side

Fig 4-B· Same knee following simultaneous transplantation of tibial tubercle and semitendinosus tendon Note the new position for the tibial tubercle and the line of the semitendinosus tendon entering the patella Note also the fixed mid-line position of the patella, even when marked pressure is exerted on its medial side

to its normal mid-line resting position. By traction on the patellar tendon, the detached tibial tubercle is shifted medially and distally on the shaft of the tibia as far as possible, which is usually one to one and a half inches below its original attachment. This point is marked and, since it lies over the broad tendinous insertion of the sartorius, the structure is opened further to expose the periosteum. Then the periosteum is outlined above and on the two sides with a scalpel, corresponding to the area where the transplant will be made. With a sharp osteotome a thick osteoperiosteal flap is reflected from above downward, with the base of elevated bone and periosteum below remaining intact. Small drill holes are made in this flap, through which the tibial tubercle is firmly anchored by means of heavy suture material. The sutures are placed through the patellar tendon and tibial tubercle at a point where firm tension will be maintained on the extensor mechanism to hold the patella in its normal position (Fig. 3-B). The patellar tendon is further anchored to the adjacent periosteum, and to the overlying sartorius tendon as it is resutured. If there is any doubt about the firm anchorage of the tibial tubercle at this point, a small screw or threaded wire should be drilled through the osteoperiosteal flap and tibial tubercle into the shaft of the tibia, although this is usually unnecessary.

Next, the tunnel is prepared through the body of the patella with a small osteotome. This is prepared from above downward so that the attachment of the tibial tubercle will not be disturbed, or the tunnel in the patella can be made before the attachment below is made. The semitendinosus tendon is then passed through this tunnel. It is firmly anchored to both the quadriceps tendon and the patellar tendon, where it is buried in grooves prepared in these two structures along the course of the transplanted tendon. Moderate tension is maintained on the transplanted tendon while the initial sutures are placed.

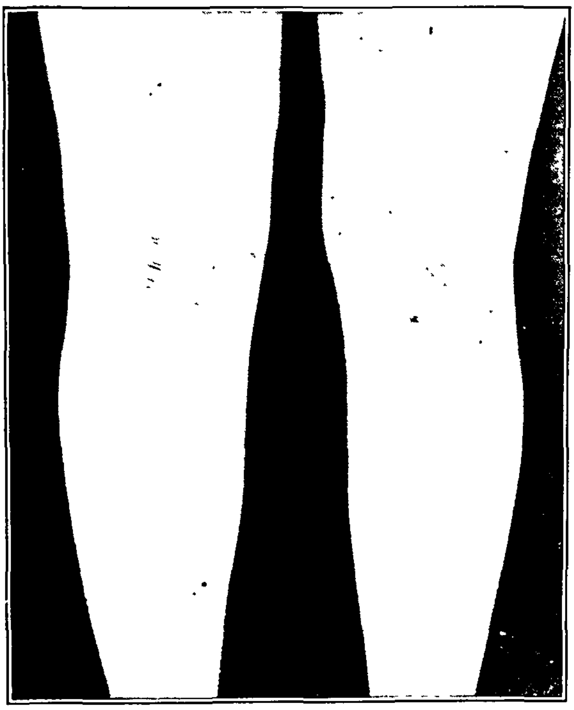

FIG. 5-A

Case 3. Recurrent dislocation of right patella, due to mild congenital relaxation and superimposed trauma. Correction by simultaneous transplantation of tibial tubercle and semitendinosus tendon at eighteen years of age. Photograph shows appearance of scar after seven years. Note the similarity of contour of the two knees.

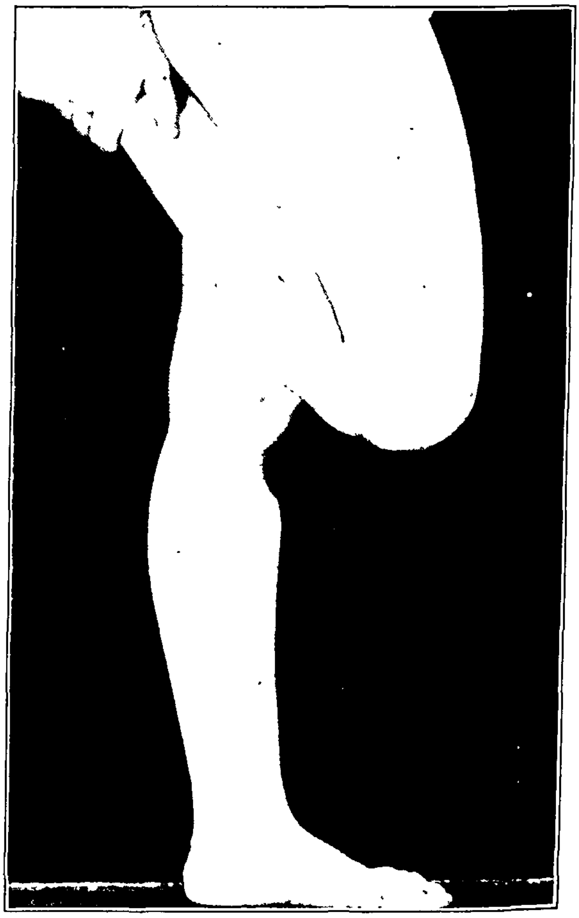

FIG. 5-B

Note the degree of flexion which is possible seven years following operation.

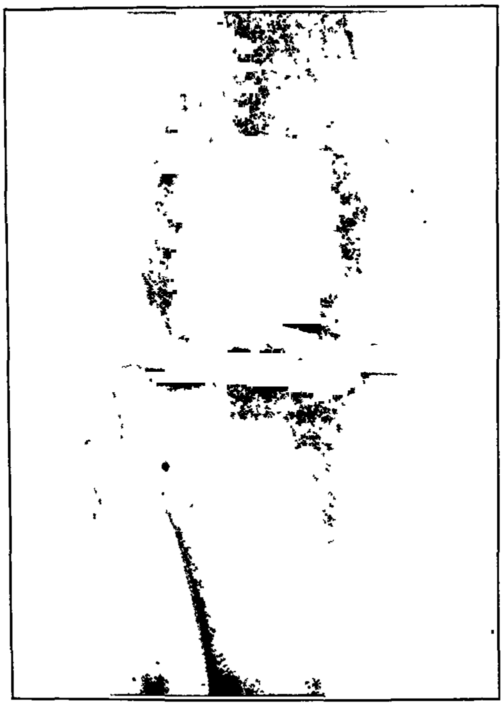

FIG. 5-C

Roentgenogram showing anteroposterior view of knee seven years following simultaneous transplantation of tibial tubercle and semitendinosus tendon. Note the mid-line position of the patella and the excess bone formation on medial aspect of tibia, marking the point of new attachment for the tibial tubercle. The knee joint itself retains its normal contour.

FIG. 5-D

Roentgenogram showing lateral view of same knee seven years after operation. Note the concavity on the anterior surface of the tibia where the tibial tubercle was detached. This was an adult knee and some bone was transplanted with the tendon. Note also the tunnel along the anterior surface of the patella, which marks the new insertion of the semitendinosus tendon. The smooth articular surface of the patella is not disturbed.

No attempt is made to close the opening in the lateral fascia. Closure is carried out in the usual way, and the extremity is encased in a plaster cast, extending from the toes to the groin. Sutures are removed after one week, but the cast is continued for four weeks. If postoperative swelling has necessitated cutting the original cast, a new one is applied when the sutures are removed. After four weeks, a skin-tight plaster cuff is applied, which extends from the upper thigh to within two inches of the malleoli. This is applied over stockinette which is anchored to the leg by skin application of an adherent. The knee is held in flexion of about 5 degrees, in order that it may be more comfortable. Weight-bearing, without crutches, is then instituted, and the patient is permitted activity. The plaster cuff is removed after another four weeks (making a total of eight weeks of immobilization), and the patient is permitted to re-establish motion in the joint by active use.

RESULTS

This procedure has been performed on twenty-three knees, twenty in children under sixteen years of age, and three in adults. Satisfactory function has been restored in all the joints, and no recurrent dislocations have followed. Cases which have not been followed for at least one year after operation are not included. The longest follow-up has been seven years, and the average is three years.

Essentially normal motion has been established in all joints. A moderate amount of traumatic arthritis was present in two of the adult knees prior to operation, presumably due to the recurring dislocations. There was definite improvement in the amount of crepitus felt on motion after operation.

SUMMARY

Simultaneous transplantation of the tibial tubercle and semitendinosus tendon for correction of lateral dislocation of the patella is a rational procedure, and not technically difficult. In twenty-three consecutive cases, there has been no recurrence of the dislocation, and satisfactory function has been maintained in all cases. Various other procedures, previously described, have failed to give the same satisfactory results in our hands.

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DELAYED PRIMARY CLOSURE OF WOUNDS WITH COMPOUND FRACTURES *

BY LIEUTENANT COLONEL MATHER CLEVELAND AND MAJOR JOHN A. GROVE

Medical Corps, Army of the United States

The initial treatment of the wounded soldier with a fracture, due to gunshot, shell, mine, or other external explosive force, consists of a careful débridement, or surgical excision of devitalized tissue. This tissue is largely muscle, the fibers of which have been killed by the enormous expansile force of the high-velocity projectile. Fascial planes are opened widely to relieve all tension. Every effort is made to conserve skin and bone, since an intact skin is essential to healing of all underlying structures, and an intact bone is essential to the proper support of the involved part. Easily accessible foreign bodies and bits of clothing are removed. A vaseline-gauze dressing is lightly inserted to the depths of the wound. This dressing is merely intended to keep the skin edges from immediately falling together, and thereby blocking drainage, should infection supervene. It is not intended, and should not be used to "pack" the wound open. The extremity is then encased in a circular plaster-of-Paris dressing to allow as comfortable transportation as possible. The forward hospitals are not held responsible for the anatomical reduction of these fractures.

The time elapsing between receiving a wound and arrival in a General Hospital, where definitive treatment of compound fractures may be instituted, has increased as the battle front has moved forward farther and farther beyond the Normandy beachhead. During the summer months following D-Day, our wounded arrived in the United Kingdom three to five days after being wounded. At the present time, the average interval is ten days to two weeks and, in some instances, much longer.

When the battle casualties with compound fractures arrive at these General Hospi-

* Read at the Annual Meeting of The British Orthopaedic Association, London, December 15, 1944.

tals, the plaster-of-Paris and vaseline dressing are removed as soon as possible, and the underlying wound and fracture are inspected. If conditions are satisfactory, skeletal traction is applied to secure proper length and alignment of the fracture.

Skeletal traction is maintained by a Kirschner wire or Steinmann pin, with the extremity in balanced suspension in an army ring splint, with a Pearson attachment for long-bone fractures of the lower extremity. The ring splint is very rarely used for upper-extremity skeletal traction. Skeletal traction secures and maintains reduction of the vast majority of these fractures of the long bones. It is continued until the fractures have consolidated or "frozen" sufficiently to ensure maintenance of position in circular plaster-of-Paris dressings, during the period of transfer to the Zone of the Interior. While these fractures are in skeletal traction, exercise of involved muscles is encouraged to secure motion in the joints above and below the fracture site. This holding period for these compound fractures varies from five to ten weeks, depending upon the site and type of the fracture. During this time every effort is made to convert the fractures from a compound to a simple state by closure of the wounds by suture or skin graft, or by employing plastic procedures, where there has been such extensive loss of skin that there is no possibility of restoring an intact integument with the tissue remaining. We have seen a great many of these wounds that can be immediately closed by suture at the time of the first dressing.

The technique of closure of these wounds should be considered at the earliest possible moment. The skin edges during the first ten days are mobile, and usually they may be readily approximated, if there is little loss of skin. A careful, minimal, secondary débridement may sometimes be required; but wet dressings of saline solution, applied for a day or two, will usually clear away the surface debris. The wound should be approximated with widely spaced and deeply placed non-absorbable sutures, without tension. If a skin graft is required, the recipient site is almost invariably treated with the wet dressing already mentioned, for approximately three days prior to operation. Delayed closure of wounds, where more than ten days to two weeks have elapsed from the time of wounding, requires removal of the new epithelium and mobilization of the skin by gentle undercutting of the edges which have become adherent. Hemostasis must be secured in any event. In either early or delayed closure, a small, rubber tissue drain is often left in the wound for twenty-four to forty-eight hours.

No attempt is made to secure a cosmetic result in these extremity wounds.

The advantages which accrue from the successful closure of these wounds are obvious. Underlying exposed bone is conserved, and healing of bone and soft tissue is accelerated. The prolonged drainage incident to healing of the wound from the depths to the surface by scar tissue is obviated. Repair of divided peripheral nerves, open reduction of such few fractures as require this procedure—with bone grafts where necessary—all may be accomplished relatively early and with greater ease.

While it is too early to state conclusively the final outcome of this type of surgery, certain facts may be presented and trends noted from statistical data, collected at several of our medical installations.

Major John Grove has collected a large series of cases from the hospital center of which he is Surgical Coordinator. Lieutenant Colonel John C. Eckells, and Lieutenant Colonel Elliott Thieme have contributed series of cases from the respective hospitals where each has been serving as Chief of Surgical Service. Major James Barr has made a very detailed study of the closure of wounds in cases of compound fractures on his Service. An attempt to briefly summarize these various observations will be made.

1. *A Study of Ninety-Seven Compound Fractures of Long Bones in Prisoners of War*

In many instances these prisoners were caught between the lines of fire and considerable delay resulted between the time of receiving the wound and the first definitive treatment. Only sixteen of these ninety-seven patients had received penicillin or other

chemotherapy prior to débridement. Only thirty-three of these ninety-seven wounds, or 34 per cent., were considered clean enough to be closed by delayed suture.

2. *A Study of Closure by Suture of the Wounds of Fifty-One Prisoners of War*

There was complete success in thirty-two cases, or 62 per cent.; partial success in fifteen, or 29 per cent.; and complete failure in four, or approximately 8 per cent.

An effort to reach any conclusions in this small series of patients yields the following:

a. *The Effect of Penicillin on Eventual Healing of the Sutured Wound*

Only seven of these fifty-one patients received any penicillin, an average of 50,000 units each, before primary surgical débridement was done; while thirty-one patients received approximately 120,000 units each, following débridement.

Of the four complete failures, two received penicillin and two did not.

b. *Time Elapsed Between Wounding and Primary Surgical Débridement in Relation to Successful Closure of Wound*

The thirty-two patients whose wounds healed promptly and completely by delayed suture included three whose primary débridement was done on the day of wounding, while the average time elapsed for the remaining twenty-nine was thirty-two hours.

Of the nineteen patients in whom closure was a complete or partial failure, débridement was done on the day of wounding in six, and in the remaining thirteen after an average of seventy-two hours.

This evidence simply furnishes corroboration of the established fact that delay between wounding and débridement favors a higher incidence of infection—often serious, as in the case of these prisoners, where gas bacillus gangrene and tetanus resulted.

3. *Certain Factors Influencing Healing of Wounds Over Compound Fractures by Delayed Primary Suture*

This is a careful study of seventy-three soldiers with 107 wounds compounding their fractures. A final closure by suture of 90 per cent. or more of the wound was considered a successful outcome in this series. The results were analyzed in relation to the following six factors:

a. Status of red blood cells and hemoglobin,
b. Location of wound,
c. Size of wound,
d. Type of discharge from wound,
e. Chemotherapy,
f. Time elapsed between wounding and closure of wound.

a. *Status of Red-Blood-Cell Count and Hemoglobin Determination*

This is of great importance. In patients with a red-cell count of two to three million cells and hemoglobin of 50 to 60 per cent., the successful closures recorded were 63 per cent. and 53 per cent., respectively; while with red-cell counts of four to five million and hemoglobin determination of 80 to 90 per cent., the closures were successful in 95 per cent. and 88 per cent., respectively. The obvious explanation is that many of our wounded require adequate blood transfusion when they arrive in General Hospitals.

b. *Location of the Wound*

With good mobility of the skin and abundant subcutaneous tissue, wounds are more readily closed. Of the wounds of the shoulder, arm, forearm, and hand, selected for closure, 100 per cent. were successfully closed and remained healed, whereas only 67 per cent. of the wounds of the leg, ankle, and foot were successfully closed and remained healed. The fact that wounds of the lower extremity are more apt to be contaminated by bacteria must also be considered in part responsible for the greater number of failures of successful closure of wounds of the leg, ankle, and foot.

c. *Size of the Wound*

The chance of closing a wound by suture varies inversely with its size. Skin grafts must be used in many of the larger wounds.

d. *Type of Discharge from the Wound*

Wounds with serous discharge may be readily closed, but, if there is a seropurulent discharge from the wound, a high percentage of failures must be expected. Basic surgical principles of course cannot be violated with impunity.

e. *Chemotherapy*

In this series of wounds, the largest number of partial or complete failures were recorded in the sixty-three wounds in patients who received penicillin, sulfadiazine, or both after admission to this hospital. It is fair to assume that this group probably consisted of the least favorable wounds from all standpoints. The use of these chemotherapeutic agents is no guarantee of success in closing wounds the bacteriology of which is unknown.

f. *Time Elapsed from Wounding to Closure*

All of these wounds were closed within thirteen days or less following wounding, and it was found that wounds closed on the thirteenth day healed and remained healed as readily as those closed on the eighth or ninth day.

4. *Closure of Wounds over Compound Fractures in a Large Hospital Center*

One of the hospital centers of our medical installations in the European Theater of Operations, during the past five months, has received and treated 5,042 compound fractures, excluding the bones of the face, skull, and spine with associated spinal-cord injury. All but a few of these fractures resulted from battle casualties. The bones of the lower extremity were involved in 2,614 instances; those of the upper extremity, in 1,895; and all others, including the pelvis, scapula, patella, clavicle, and vertebrae in that order, comprised a group of 533. The bones most frequently fractured were the tibia (757), humerus (702), and femur (684). Fractures of the long bones were, for the most part, treated with skeletal traction and balanced suspension.

Delayed primary closure of the wounds of these compound fractures was attempted in 2,393 patients. The average time between wounding and closure of the wound in this series was fourteen days. Closure of the wound was accomplished by suture in 2,087 cases, by skin graft in 236, and by combination of suture and skin graft in seventy cases.

In many large wounds with frank infection, a partial closure of the wound was performed with free drainage at the site of maximum infection, and at times counterincision was made for dependent drainage. The partial closure of large draining surfaces prevents loss of serum, and is accompanied by marked improvement in the patient's general condition.

In this extensive series of cases, it was noted that anaemia was common, and transfusions of whole blood were frequently required to build up the patient's general condition.

Elevation of the wounded extremity, and skeletal traction with balanced suspension reduced the oedema of the part, and facilitated closure of the wound.

Skin-grafting by split-thickness free grafts has been done with increasing frequency; and in wounds with considerable loss of bone and soft tissue, especially those of the hands, feet, and forearms, pedicle grafts are being employed. These pedicle grafts are performed at those hospitals designated for plastic surgery.

Results of Surgical Closure: The results of the attempts to convert these compound fractures into simple fractures were as follows:

a. *Complete success* with healing by primary intention occurred in 1,592 cases, or 66.53 per cent. of the total.

b. *Partial failure* occurred in 640 cases, or 26.74 per cent. of the total.

Those cases rated as partial failures showed a small sinus, a stitch abscess, or a par-

tial loss of a skin graft. All but a very few of these wounds, counted as partial failures, healed by a second suture or skin graft or spontaneously, and were healed when the patients left the hospital. This means that a total of 93 per cent. of the patients in whom closures were attempted left the hospital with their wounds healed.

c. *Complete failure* occurred in 161 cases or 6.73 per cent. of the total.

By complete failure is meant an entire breaking open of the wound spontaneously, or the development of an osteomyelitis which necessitated the wide opening of the wound surgically.

Common sites for these complete failures were wounds involving the upper third of the femur, or the pelvis, complicated by penetration of bladder or bowel. The wounds involving the lower third of the leg and foot also ranked high among the complete failures. Cultures of bacteria from these wounds, which failed to heal, revealed a mixed type of infection with staphylococci and bacilli of the colon group predominating.

Spontaneous Healing of Compound Fractures: It is interesting to note that among these 5,042 compound fractures, 2,152 cases, or approximately 42 per cent. of the total, showed spontaneous healing of the wounds during the period the patients were hospitalized in this theater of operations. The majority of these were small penetrating or perforating wounds.

Healing of the Wounds of the Entire 5,042 Compound Fractures: In this series of patients, failure of healing was noted in 161 unsuccessful attempts at closure, and in 497 of the 2,649 patients on whom no attempt at surgical closure was made,—a total of 658 wounds which failed to heal in the entire 5,042 cases. The maximum holding period for these patients in this theater of operations is approximately ten to twelve weeks, depending upon the fracture. It is significant that within this time, 87 per cent. of these fractures were converted from compound to simple state by healing of the wounds.

Osteomyelitis: Frank infection of the fractured bone was noted in 272 patients, an incidence of 5.4 per cent. of the total.

SUMMARY

Delayed primary closure of wounds over compound fractures can be accomplished by surgical means in a very high percentage of battle casualties. In a series of 2,393 closures of wounds over compound fractures, 93 per cent. had healed when the patients left the hospital.

The factors which seem to influence the success of this treatment are:

(1) *Early and adequate surgical débridement* of the wound.

(2) *Rapid evacuation* of the wounded to the rear medical installations, where this definitive treatment may be carried out.

(3) *A low incidence of serious infection,* which is due to the early surgical treatment mentioned above, and to the age and generally excellent physical condition of the patients involved. The use of sulfonamides and penicillin probably exerts a beneficial influence on this low incidence of infection. Controlled experimental proof of this is not available.

(4) *Whole-blood transfusions* to combat the anaemia, which is present in many of these wounded, ensure a higher percentage of successful surgical closures of wounds.

EXPERIENCE WITH WHOLE BLOOD AND PLASMA *

BY CAPTAIN FOREST H. COULSON

Medical Corps, Army of the United States

In the preinvasion planning for the use of whole blood in casualties among the United States Forces, estimates were made that plasma would be sufficient to restore blood volume in nine wounded out of ten. The tenth man would need a blood transfusion and, even in his case, plasma would be used in the ratio of two units for one of whole blood.

The European-Theater-of-Operations Blood Bank was established to supply units of Type O whole blood to Clearing Stations, Field Hospitals, and Evacuation Hospitals in the Army Area, and to Station and General Hospitals in the Communications Zone. It was felt that these units would be unable to supply whole blood in sufficient quantities for their needs, or to practise a technique suitable for the preparation of intravenous fluids under field conditions.

Whole blood has been shipped by air transport almost daily since June 13, 1944, from the Blood Bank to Blood Bank Detachments in France. During the first week of the invasion it was carried to the beaches on LST's (Landing Ship Tanks) and Hospital Carriers. The units of blood were packed for the journey in Quartermaster refrigerator cans with ice as the refrigerant. Delivery to medical units was made by detachments of the Blood Bank, equipped with refrigerators on trucks.

Within the first month after D-Day, it became apparent that the E. T. O. Blood Bank alone could not furnish all of the Type O blood, demanded by medical units in France. A call was made to the United States for a daily supply of whole blood to supplement that produced in the United Kingdom. There had been no lull in the activities of the American Red Cross in the United States in securing blood from civilians for the supply of plasma. Under the direction of the Surgeon General, part of the blood collected in Washington, New York, and Boston was used to help meet the unexpected demand. As a preservative, 500 cubic centimeters of Alsever's solution was used, when the blood was not refrigerated during the flight to the United Kingdom. It was determined that in this solution there was not sufficient hemolysis of red cells to be dangerous to the recipient.

On August 24, the first shipment of blood from the United States landed at an airport in Scotland, and daily shipments were received there until the planes from the United States could land directly in Paris. After twenty-four hours of refrigeration, supervised by a Blood Bank Detachment, the blood was flown from Scotland to France, where it was combined with shipments from the E. T. O. Blood Bank, and distributed to the medical units.

A third source of whole blood has appeared with the establishment of the second E. T. O. Blood Bank, which has been operating in Paris since November 1.

There are three main reasons for the use of blood, far in excess of expectations. First, when there has been a rapid and copious loss of blood, plasma alone has been found insufficient. This condition is an indication for immediate transfusions of whole blood, and as many as four or five units have been given to these patients over a period of a few hours. Only in casualties with relatively small loss of blood or slow hemorrhage can plasma be used to restore part or all of the blood volume. Second, emergency surgical procedures requiring the support of whole blood, preoperatively and postoperatively, are being done more frequently and farther forward in the line of evacuation than was expected. A third cause of the great demand is the fact that whole blood has become so readily available through the Blood Bank. Furthermore, it is so easy to use, when typing and crossmatch-

* Read at the Annual Meeting of The British Orthopaedic Association, London, December 15, 1944.

ing are not necessary, that it is being used to support patients with gas gangrene and othe severe infections during their course of therapy with sulfadiazine and penicillin.

Accurate figures, showing the actual comparison in the use of plasma and whole bloo for war casualties, are not yet available; but certainly the ratio will not be that expecte before D-Day.

TRANSPORTATION OF THE WOUNDED SOLDIER *

BY LIEUTENANT COLONEL JOHN G. MANNING
Medical Corps, Army of the United States

It is the policy of the Medical Corps of the United States Army to transport the wounded soldier to the rear as rapidly as possible, and to administer definitive therapy in General Hospitals. At the present time, all patients with fractures of the long bones are transported to General Hospitals in the United Kingdom, where the fractures are reduced by skeletal traction, and delayed primary wound closures are performed to convert compound fractures into simple fractures. The long journey from the front line is made in short trips by ambulance, hospital train, and hospital ship, or by airplane. If airplane travel is not available, ten to fourteen days are usually required to move the wounded soldier from the German border to a General Hospital in the United Kingdom.

The care given to the soldier in the forward areas and during transit is directed toward the relief of pain, prevention and treatment of shock and infection, and ensuring comfort.

From the battlefield to the Battalion Aid Station the wounded are carried either by litter bearers, or by litter-carrying jeeps. As much use as possible is made of the jeeps, to save both time and labor. Armored vehicles are sometimes used, especially if the battle is quite active. The time required to move the wounded back to the Aid Station varies considerably, depending upon weather, terrain, and battle conditions. Under favorable circumstances, however, it is possible to remove the majority of litter cases in half an hour.

At the Battalion Aid Station, the first real opportunity is afforded to apply an adequate splint for fracture of the long bones. The Army half-ring leg splint, with ankle traction strap, is put on for fractures of the thigh and leg. Velpeau's bandage is applied for fractures of the humerus, and wire ladder splints for fractures of the forearm and wrist, and ankle and foot. After the soldier's wounds have been dressed, splints applied, and morphine and sulfonamides administered, he is transported by ambulance to a col-

* Read at the Annual Meeting of The British Orthopaedic Association, London, December 15, 1944.

lecting point, called the collecting company. This ambulance haul usually takes from ten to fifteen minutes. At this point, cases are sorted, and those soldiers requiring further first-aid treatment, application or reapplication of splints, or resuscitation are held until that treatment can be administered, while the others are transported on to the clearing company. During the month of November, the majority of cases arrived back at the clearing company within an interval of two to four hours from time of wounding. At this installation, penicillin is administered, and blood and oxygen are available for resuscitation. Here, further sorting is done, and a few men remain at this point for treatment. The patients who are able to be transported are sent by ambulance to the Evacuation Hospitals, five to twenty-five miles to the rear. The cases of abdominal and chest wounds and other patients who, in the opinion of the medical officer, will not tolerate a long ambulance ride, are sent to the Field Hospital which is set up within a few hundred yards of the clearing company. This is the farthest forward medical installation which is equipped to perform primary surgical treatment.

At the Evacuation Hospital where most of the extremity wounds receive primary surgical treatment, another sorting occurs to determine priority for surgery. Careful débridement of the wounds is performed, and the fractures are immobilized in circular plaster-of-Paris splints for transportation. These plaster splints are not intended to hold the extremity in reduction, or even in good alignment, but are for the purpose of immobilization of the bone and soft tissue, so that the soldier can be transported comfortably. Evacuation and Field Hospitals are the first medical installations in which plaster-of-Paris splints are applied. The following splints are used: circular plaster for fractures of the bones of the forearm; Velpeau's plaster bandage, and shoulder spica for fractures of the shoulder and humerus; double plaster-of-Paris spica for fractures of the femur; long circular plaster-of-Paris for fractures of the tibia and fibula; short circular plaster splints for fractures of the foot. All circular plasters applied to extremities are split down to the skin so as to divide all circular dressings. The majority of patients with fractures which do not have other complicating lesions are ready for transportation within twenty-four to thirty-six hours after débridement has been performed.

From the Field and Evacuation Hospitals the soldier is again transported by ambulance to a center which is served by hospital trains, or which has airfields located nearby. In this center there are usually a number of General Hospitals which serve as Transit Hospitals. The time required for the ambulance trip from the Evacuation Hospital to the General Hospital again varies with the distance, but is usually not more than two to three hours. At the Transit Hospitals the chemotherapy is continued, and any complication which may have arisen is dealt with. As soon as a hospital train is available for loading, the men are transported to it by ambulance. The trip by hospital train to another hospital center usually takes twenty-four hours. The patients are then held in another Transit Hospital either for air evacuation or transfer to another hospital train, which will take them to a port. This trip requires twenty-four to thirty-six hours. At the port the men are again held in a hospital for transport by air if available, or for transfer to a hospital ship. The hospital ship crossing requires twelve to twenty-four hours. The patients will again be held in a Transit Hospital until a hospital train is available. From the hospital train they are transported by ambulance to the General Hospital in the United Kingdom.

If they are transported by air, they will arrive at an airfield in the United Kingdom, pass to Transit Hospitals by ambulance, thence to hospital train, and by ambulance to the General Hospital.

The journey is a long one, but the patients have been able to tolerate it, because all along the route of evacuation they have received medical attention, and have been given good general care. Although the time required for evacuation is very long, we believe that, except in a few instances, it has not jeopardized the soldier's life or limb.

THE INTERVERTEBRAL DISC: ITS MICROSCOPIC ANATOMY AND PATHOLOGY

Part III. Pathological Changes in the Intervertebral Disc

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In previous papers * we have discussed the anatomy, development, and physiology of the intervertebral disc, and the changes in it concomitant with age. The borderline is indistinct between the degenerative changes accompanying the aging process, and those that may be termed pathological. In many instances, it is difficult to know where one ends and the other begins. While destruction of a disc by infection is definitely pathological, there are the additional changes produced by senescent arthritis or nuclear expansion. In lesser degrees both of these changes are so often encountered in certain age periods as to be considered normal. However, in their more advanced forms, they are abnormal or pathological. Usually, pathological changes are manifested in the roentgenogram of the gross specimen by such phenomena as thinning, "ballooning", and calcification of the nucleus. However, microscopic changes which are not visible by roentgenogram may also be pathological.

TABLE I
Incidence of Pathological Discs

Pathological Changes	Number of Cases
Nuclear expansion	7
Ballooning	5
Thinning	9
Intraspongy nuclear protrusions (Schmorl bodies)	
Microscopic	56
(Gross . . . 5)	
Anterior nuclear protrusions	1
Posterior nuclear protrusions	7
Calcified nucleus pulposus	1
Invasion by infection	1
Invasion by malignancy	1
Total	88 *

* Routine necropsy specimens 85; added cases 3.

The pathological changes to be discussed have been found in discs removed during routine necropsy, with the exception of three cases which were added to complete the study. These added specimens showed: (1) a disc invaded by carcinoma; (2) a disc destroyed by infection; and (3) a disc in the thoracic region from a case of senile osteoporosis. In considering Table I, it should be remembered that the incidence of pathological discs found in this study only approximates the actual incidence of pathological discs in the patients studied. It has been impossible to determine in how many cases there were bony spurs, for a microscopic section takes in only a very small amount of a disc and the adjacent vertebrae. The same may be said of all the other pathological affections, although a disc which has undergone definite pathological changes usually exhibits some of these changes in all of its parts. Of course, the recorded incidence of pathological specimens, in which diagnoses were made from the thinning, ballooning, nuclear expansion, calcifi-

* See Part I (p. 105, January 1945) and Part II (p. 233, April 1945).

cation, and Schmorl bodies visible in the roentgenograms, is fairly accurate, and of some significance.

A. HYPERTROPHIC ARTHRITIS

Beadle, quoting Schmorl's work, stated that the osteophytes form just below the outer edge of the epiphyseal ring on the front and sides of the vertebral bodies. They may grow to enormous size, and may fuse with the adjacent spurs from above or below. They appear to be linked by calcification in the longitudinal ligaments, often seen in spondylitis deformans.

The cause of osteophytic growth in the spinal column was first expounded by Beneke, in 1897. His theory was that because of degeneration, with resultant loss of disc substance, there is increased movability of the vertebral bodies on one another. As the motion increases, tension is placed on the attachment of the longitudinal ligament above and below the disc anteriorly. The ligaments are implanted deeply in the bone as Sharpey fibers. This pulling stimulates the periosteum to formation of new bone, much as the tension on tendinous attachments among children causes characteristic bony ridges and tubercles.

Why osteophytes do not usually occur posteriorly is also explained by this hypothesis. Since the posterior longitudinal ligament is not attached firmly to bone, tension on it tears the annulus, to which it is adherent, but does not stimulate the periosteum to any extent.

Donohue modified this hypothesis of the causation of osteophytic growths by stating that it is the lateral and anterior bulging of hypermobile, degenerated discs that stretches the ligaments and in turn pulls on the periosteum, causing it to create new bone.

B. NUCLEAR EXPANSION

The majority of the discs in the lumbosacral region, beyond the age of fifteen years or so, exhibit a varying degree of what is spoken of as nuclear expansion. For this reason

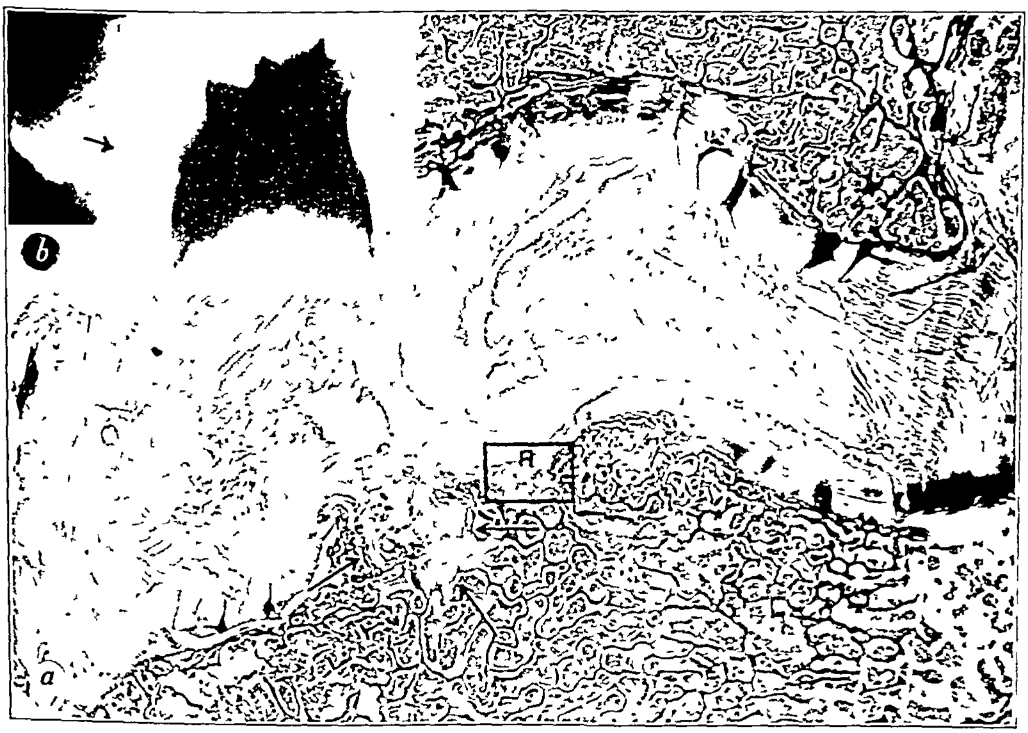

Fig. 1

Intervertebral disc of a youth, aged twenty years. *a* Section (×3.75), showing nuclear expansion. Arrows indicate a Schmorl body. *A* (box) is enlarged as Fig 5 of Part II of this series of papers *b*. Roentgenogram. The arrow indicates a Schmorl body.

one hesitates to classify nuclear expansion as a pathological entity. As the name implies, there is expansion of the disc in the region of the nucleus pulposus, at the junction of the middle and posterior thirds of the disc. This occurs most prominently in the lumbar region. This expansion is physiological rather than pathological, except in its marked degrees, in which it may truly be termed abnormal (Fig. 1,*a* and *b*). Seven cases of marked expansion—that is, expansion enough to be termed pathological—have been encountered in this study.

Nuclear expansion is due to the turgor and potential force in the nucleus pulposus. It is natural for the nucleus, under tension, to expand somewhat into the adjacent bone. This bone is not osteoporotic in the disc which shows nuclear expansion. When osteoporosis is present, ballooning takes place instead. This is a diffuse, rather than a localized, expansion. Schmorl found nuclear expansion at very early ages, and expressed the belief that it is caused by developmental defects in the cartilaginous plate. Beadle qualified this, stating that it results from slight trauma to a spinal column in which there is an unexplained congenital weakness. No one, however, has explained why expansion does not occur in discs in which there are multiple defects of the cartilaginous plates. Some of the specimens in this study have all the factors that one would think necessary for marked expansion, but none occurs. The fact that expansions occur most commonly in the young middle-age group supports Übermuth's contention that it is at this time that the nucleus functions most strongly and is at its "high-water-mark".

This study has confirmed most of Schmorl's observations on nuclear expansion,—namely, thinning of the cartilaginous plate at the point of maximal bulge (this could theoretically be a result rather than a cause of expansion), and defects in the region of the bulge, with occasional nuclear protrusions. The nucleus is in good condition,—that is, in specimens exhibiting expansion, it is not fibrotic or desiccated. Perhaps the only cause for nuclear expansion is that the nucleus itself has an abnormally high water content, with resulting increased tension. At any rate, nuclear expansion, even when it is considerable, probably does not produce clinical symptoms.

FIG. 2-A

Ballooned intervertebral disc (× 3.5) of a man, aged sixty years, suffering from osteoporosis.

C. BALLOONED DISCS ("FISH VERTEBRAE")

Ballooning of the intervertebral disc is found in osteoporosis. This is a disease of unknown origin, affecting the entire spinal column and often the pelvic bones. It usually is encountered among persons beyond middle life. It is most frequent among women following the climacteric. The clinical aspects of osteoporosis are adequately discussed by Black, Ghormley, and Camp. The bone of the vertebrae is changed so that the trabeculae of the substantia spongiosa are decreased in size and number, and replaced by bone marrow. This removes the struts that give strength to the bone, which in consequence becomes more easily collapsible than in its normal state.

FIG. 2-B
Roentgenogram of the intervertebral disc shown in Fig. 2-A.

To have ballooning of the disc, even when osteoporosis is present, one must have a fairly normal disc, one that is expansile and elastic (Schmorl). Otherwise anterior wedging and narrowing of the vertebrae may occur and the disc may remain normal in thickness. In addition, there must be certain stresses placed on the disc to mold it into the characteristic lens shape. The increase of the size of the disc is most probably due to an increase of water content and not to an actual increase of tissue.

Why does the greatest indentation occur at the center of the vertebra? Schmorl proposed two reasons: First, it is approximately here that the elastic gelatinous nucleus is most active (although it is actually placed slightly posteriorly); secondly, here the adjacent vertebra is the weakest, because of the multiple small perforations located centrally in the bony plate.

Ballooning of discs occurs chiefly in the lumbar and lower thoracic regions, for here the discs are larger and apparently have more expansile force than in other regions (Figs. 2-A and 2-B). The stress is directed vertically, and less in the curved direction which is seen higher in the thoracic region. In the thoracic portion of the spinal column, while ballooning may occur to some extent, the chief deformity is usually a wedging of the vertebrae with the lower height anteriorly. Here, because of the kyphosis normally present, the anterior edges of the vertebrae take most of the force, and compression often occurs (Fig. 3).

Five patients in this study showed evidence of moderate to marked ballooning. One was forty-nine years old. The others were all in the sixties. Three were men and two were women (although osteoporosis is more common among women than among men). Microscopically, the following changes were observed. The vertebral bodies showed lessening in number and width of the trabeculae. The discs were larger than normal, but less dense, for the same amount of tissue had an added amount of fluid to take up the space formed by the expansion of the disc. The nucleus showed very little evidence of degeneration, and its tissue substances were separated by fluid. Many small cavities and vacuoles were found. The annulus was stretched, and more spherical than usual. Donohue stated that rupture of the cartilaginous plate is frequent and prolapses without reaction are common. However, we found no more defects of the cartilaginous plate or microscopic protrusions of nuclear material in the ballooned discs than in other discs of a comparable age group. The cartilaginous plates did not seem to be thinned, though this was questionable in some specimens. Thus from our observations the discs were in as good a condition as those of comparable age groups where ballooning did not occur, and, except for their increase in size, might fall within the norm for their age. This is due in turn to their increased fluid content, which causes a looser arrangement of the cellular elements in the disc.

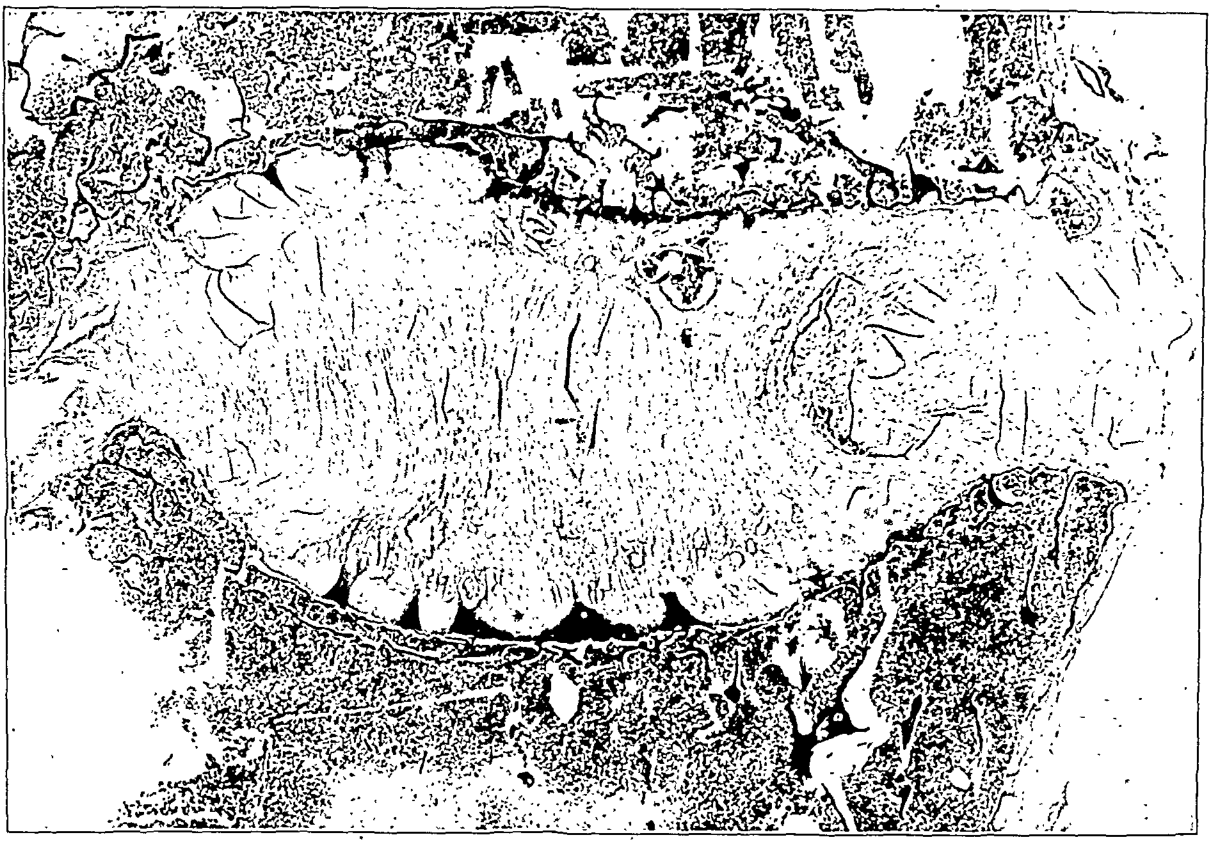

FIG. 3

Ballooned intervertebral disc from the thoracic portion of the spinal column of a woman, aged seventy-seven years, suffering from osteoporosis. (× 3.5.)

D. THINNED DISCS

While it is recognized that thinning of the intervertebral disc is relative, the diagnosis can be made rather definitely by roentgenographic examination or by examining a microscopic section grossly. Both methods have been used in this study, and only when both show moderate to marked thinning have the discs been termed pathological. Nine of the eighty-eight specimens in this study showed thinning of the disc. Horwitz, examining the spinal columns of seventy-five cadavera grossly, found fifty that showed evidence of lumbosacral narrowing. His subjects were aged forty-five to ninety years. There are three obvious reasons for the discrepancy in incidence of thinning: (1) In this study a double check was made, as indicated previously, in order that only definitely thinned discs should be used for microscopic examination; (2) many of our subjects were below the age of forty-five years, when thinning is less common than at greater ages; and (3) only moderate to marked thinning of the lumbosacral disc has been considered in this study. The majority of the thinned discs found in this study are in the fifty-year to seventy-year age groups, however, and none were found below the age of twenty-one years.

What is the causation of the thinned disc? Microscopically, they may be classified into two groups. Group 1 is made up of those in which the annulus and the cartilaginous plate are intact, and in which there is no evidence of invading fibrous and granulation tissue. Three of the specimens fall within this group. There are desiccation and necrosis of the nucleus pulposus. Apparently the fluid content of the disc has been markedly diminished; and, as fluid normally comprises a high percentage of the total volume, there is loss of actual space-occupying material in the disc. The disc, therefore, becomes collapsed and smaller than normal. *The roentgenograms in this group show thinning, with very* little marginal sclerosis of the end plate and very little hypertrophic spurring (Fig. 4,*a* and *b*).

Group 2 consists of thinned intervertebral discs in which the cause of the thinning is more evident than in Group 1. Either the annulus is ruptured, usually posteriorly, or the

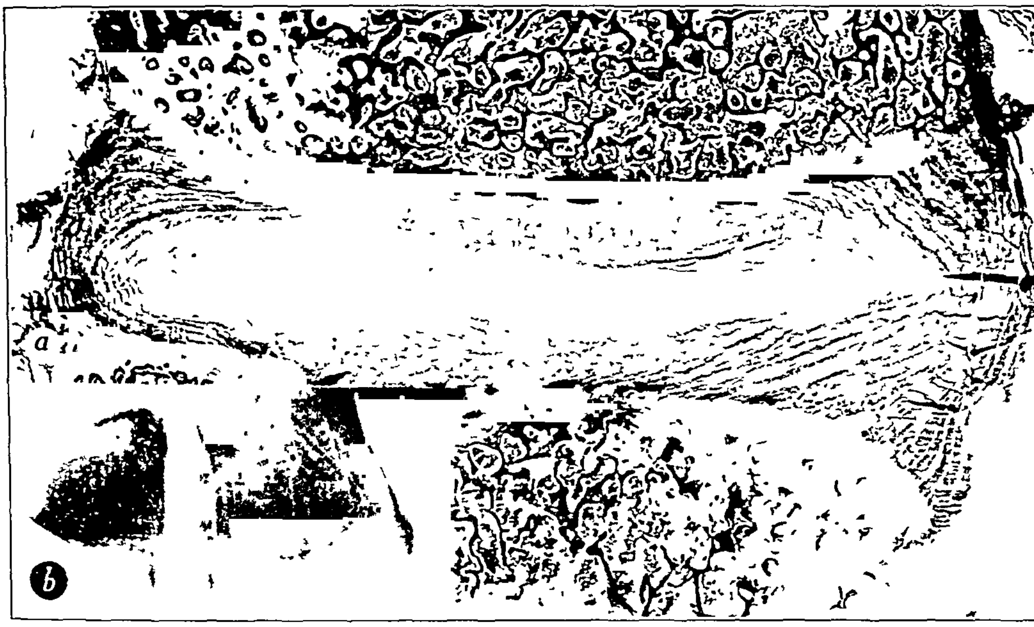

FIG. 4
Thinned intervertebral disc of a woman, aged twenty-nine years. *a*. Section (× 5). The loss of substance in the lower anterior aspect is an artefact. *b*. Roentgenogram.

cartilaginous plate contains many defects, or both. Six of nine cases fall in this group. The nuclear material flows out through these openings in the annulus or cartilaginous plate, with resulting loss of disc tissue and consequent thinning. This is a purely mechanical phenomenon. In addition, blood vessels and fibroblasts invade the disc through the openings in the annulus or cartilaginous plate, and this may "open avenues for dehydration of the disc" as Compere and Keyes have emphasized. In time these invading cells may completely replace the normal cells of the disc. Figure 5,*a* and *b* is an example of the second type of thinned disc. The roentgenograms in this second group invariably show some marginal sclerosis, and fairly frequently they show osteophytic reaction.

Dehydration is the essential cause, then, of the thinning of the disc. Why this occurs in Group 1 is not entirely clear. We have shown that in Group 2 it is due to the invasion of the disc material by blood vessels and fibrous tissue, opening avenues of dehydration. These invade the disc through defects in the annulus and in the cartilaginous plate. The cause of these defects has been discussed elsewhere. It should be emphasized here that Pease has shown how the penetration of the posterior portion of the annulus with the lumbar puncture needle can result in thinning of the disc. Gellman has also reported a case of injury to the disc in this same manner. Thinning of the disc by infection is another problem and will be discussed later.

To complete this picture of the thinning of the disc, the end result should be discussed. One of the specimens in this study (Fig. 6,*a* and *b*) showed complete obliteration of the disc, with resulting bony ankylosis. This was probably not the usual picture, for most lumbosacral discs, though they may be almost completely destroyed, are usually not invaded by bone, and ankylosis of the fifth lumbar to the first sacral segment is uncommon. The almost complete destruction of the disc, with bony ankylosis, is more likely to be the result of spondylitis deformans or of infection. The specimen shows bony continuity between the adjacent vertebrae, with islands of disc tissue remaining here and there. Very little of the annulus fibrosus remains, but there are intact regions of cartilaginous plate and occasional nests of nuclear material. The roentgenogram confirms the bony ankylosis between vertebrae. Schmorl emphasized that once ankylosis has occurred, its cause cannot be determined microscopically or roentgenographically.

E. INTRASPONGY NUCLEAR HERNIATIONS ("SCHMORL BODIES")

A Schmorl body may be defined as the herniation of disc substance through the cartilaginous plate into the body of the adjacent vertebra. Known also as Schmorl node or nodule, disc prolapse, cartilage node, or intraspongy nuclear hernia (Calvé and Galland), this phenomenon was first described by von Luschka in 1858, and "rediscovered" by Schmorl in 1927. The herniation occurs through a defect in the cartilaginous plate, and extends a varying distance into the cancellous bone of the adjacent vertebra. In youth the defect in the cartilaginous plate is probably partly developmental. Herniations occur in a row, opposite the region of greatest nuclear expansion. They are usually quite uniform in size and shape. In older spinal columns they tend to be single, to pass through larger defects in the cartilaginous plate, and to be highly irregular in size and shape. A reactive change occurs in the bone around the herniation, usually in the form of bony sclerosis. The prolapse itself tends to change over to cartilage, especially at the periphery, and even tends to ossify in time. This is thought to be nature's way of attempting to solidify the herniation, and plug the hole through which the disc escapes. Granulation tissue often grows from the marrow into the disc by way of the herniation. This vascularization and cicatrization can be seen grossly as dark reddish infiltration of the nucleus pulposus. For further details as to anatomy of the Schmorl body, one may read excellent descriptions by Schmorl, Beadle, Calvé and Galland, Sashin, Donohue, and others.

These herniations occur in the spinal columns of young persons rather rapidly after trauma because of the turgor present in the disc. But in the spinal columns of older persons, with loss of fluid in the nucleus, the herniation probably occurs gradually, and is due to the actual force of the cephalad vertebra on the caudad vertebra, with the disc interposed, so that a "squeezing out" process occurs. Schmorl bodies have been produced experimentally among dogs by producing defects in the cartilaginous plate.[8]

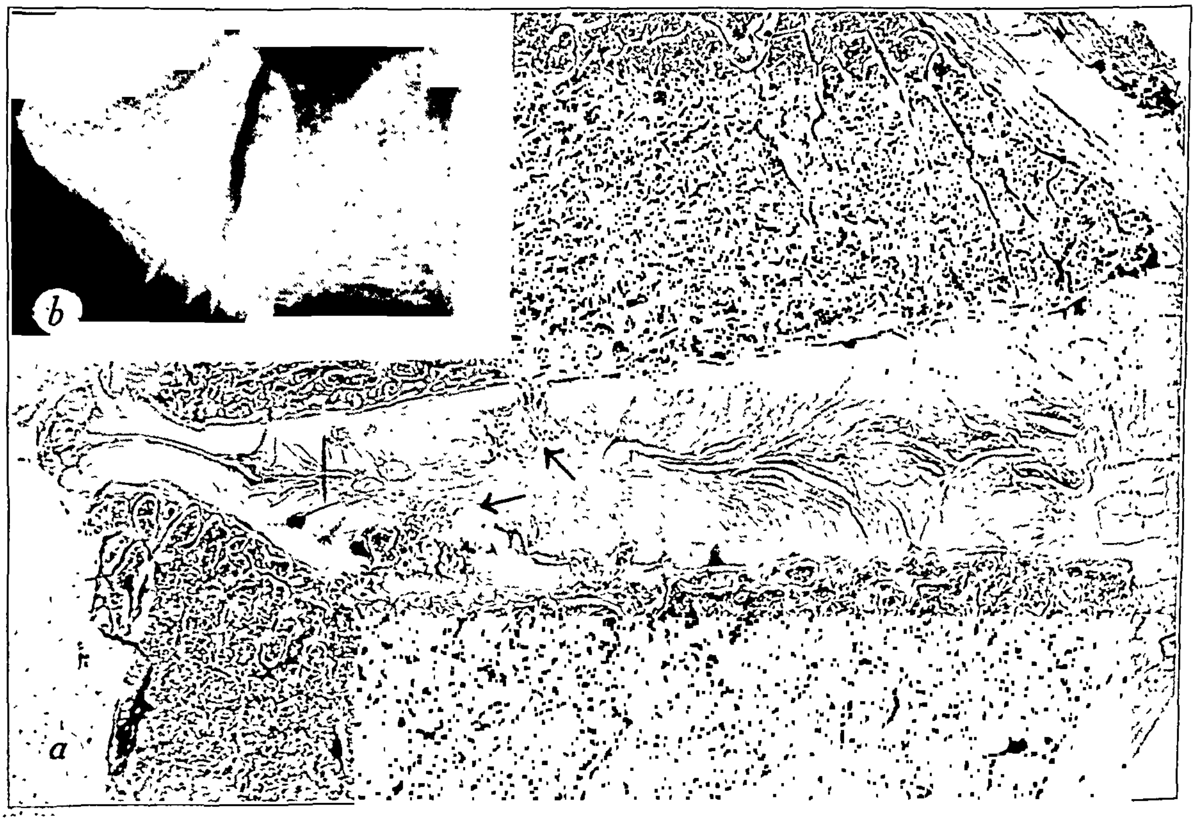

Fig. 5

Thinned intervertebral disc of a man, aged seventy years, with marked sclerosis of adjacent vertebrae. *a*. Section (× 3.5). Arrows point to invading blood vessels. There is posterior protrusion of nuclear material. *b*. Roentgenogram.

FIG. 6
Obliteration of intervertebral disc of a woman, aged sixty-five years, and consequent bony ankylosis. *a.* Section (× 4). *b.* Roentgenogram.

The herniation must be more clearly defined, in order that the facts of this study may be presented. Beadle stated that herniations just visible to the naked eye are the smallest that should be included. However, he also stated that prolapses may be just through the cartilaginous plate, and these are usually not visible to the naked eye. Our study includes all prolapses that can be seen grossly or microscopically. A tear, through which there streams out nuclear material which stops at the bone of the vertebra, is included here as a herniation.

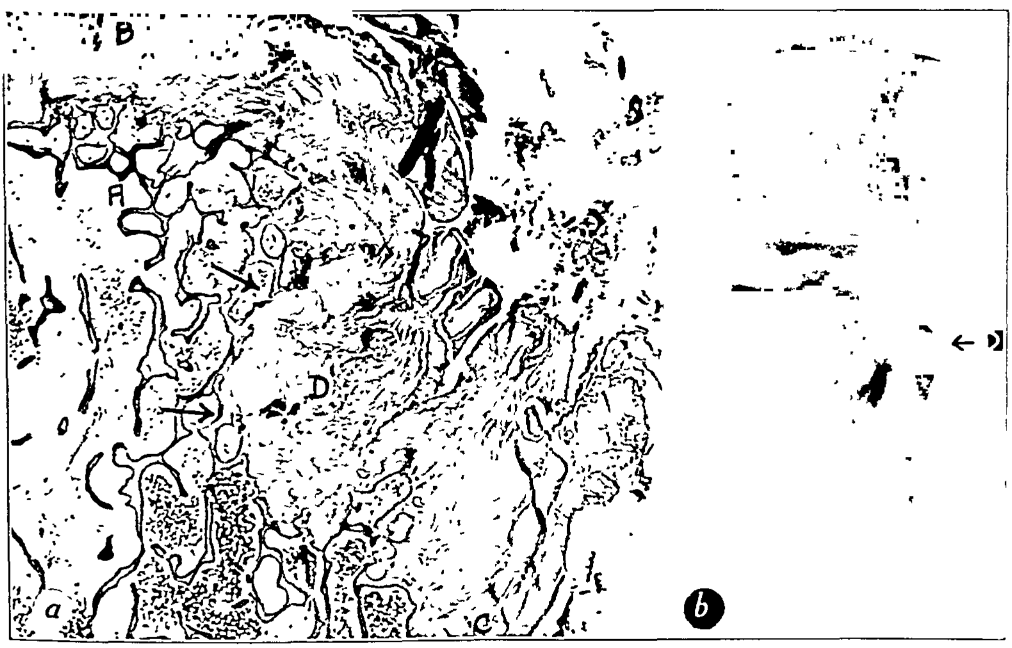

FIG. 7
Intervertebral disc of a woman, aged sixty-eight years. *a.* Section (× 9). *A.* Bony rim. *B*: Anterior portion of annulus fibrosus. *C*: Anterior longitudinal ligament. *D*: Protruded nuclear material. *b.* Roentgenogram. *D*: Protruded nuclear material.

TABLE II

INCIDENCE OF MICROSCOPIC INTRASPONGY HERNIATIONS

Decade	Specimens	Herniations	Herniations (Per cent.)
1	5	0	0
2	6	1	17
3	8	2	25
4	9	5	55
5	11	8	73
6	22	18	82
7	16	14	87
8	11	8	73
	88	56	63.63

Schmorl found that herniations occurred in 38 per cent. of all spinal columns examined by him. Batts in a postmortem study of gross specimens found 20 per cent. of spinal columns showing herniations visible to the naked eye. The present study concerns itself only with the lumbosacral region, and only with microscopic and roentgenographic studies. In eighty-eight specimens, only two showed herniations large enough to be seen in a roentgenogram (Figs. 1,*b* and 7,*b*). Three additional sections showed herniations large enough to be seen grossly, if the slide was held up to the light. However, by far the majority of sections examined showed multiple microscopic herniations, most of them passing through the cartilaginous plate and ending just after penetrating the bone. Table II shows the incidence of these microscopic herniations.

This is evidence that the protective forces at play are great, and that only a relatively few herniations actually pass very far into the adjacent vertebral bodies. These defects of the cartilaginous plate with microscopic herniations probably are not very serious in themselves. They are so frequent, especially in the later age groups, as to be almost normal.

Two requirements are necessary for an intraspongy nuclear herniation to be visible on a roentgenogram: (1) The herniation must be large enough to be seen with the naked eye; and (2) there must be enough sclerosis around the margin of the herniation to cast a shadow of increased density to the roentgen rays.

One of the sections in this study had a nuclear herniation into an adjacent vertebra which had been invaded by metastatic carcinoma (Figs. 8-A and 8-B). The herniation is almost spherical and comes through a very small defect in the cartilaginous plate. The herniation contains chiefly degenerated nuclear material. There is very little proliferation of cartilage cells, or other reaction. The bone of the vertebra is almost completely gone and has been replaced by loose, oedematous granulation tissue. Next to this tissue is the metastatic carcinoma (prostate). This is an excellent example of what happens when the cartilaginous plate breaks, and there is no force on the opposite side to prevent herniation of the nucleus. Not only does the nuclear material extrude into the destroyed vertebral tissue, but the normal reactive processes of the body are lost and a walling-off process cannot take place.

Though this is not in any way a clinical study, we should like to summarize the opinions regarding the clinical significance of Schmorl bodies. Schmorl believed that they were not the cause of clinical symptoms, though he had very few clinical data to work with. Donohue stated that the majority did not evoke clinical symptoms. Geist, on the other hand, expressed the opinion that they do cause clinical symptoms. The probable answer is that the herniation itself is not particularly painful, but that the symptoms are caused by the result of the herniation, as has been suggested by Schanz. If much of the disc tissue escapes, and the disc becomes degenerated and thinned, added strain is placed on the ligaments about the disc. Also, the axis of motion may be displaced posteriorly, as suggested by Keyes and Compere, placing the strain on the articular facets.

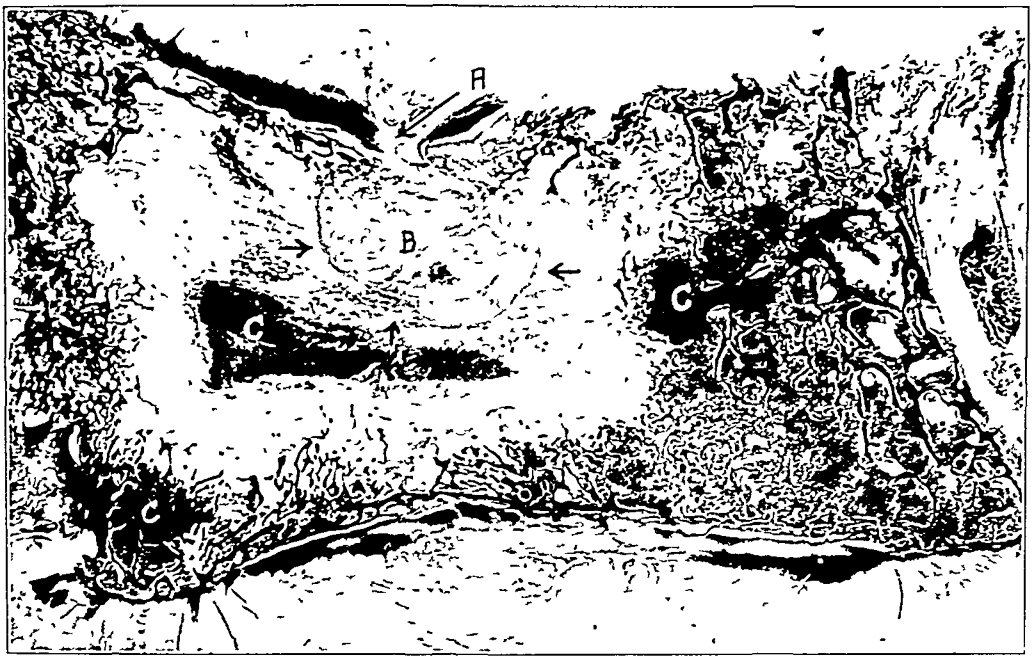

FIG 8-A

Schmorl body in a vertebra of a man, aged seventy-five years, suffering from metastatic carcinoma *A* Break in cartilaginous plate *B* Protruded nuclear material (Schmorl body) *C* Metastatic carcinoma (× 3.5)

F. ANTERIOR NUCLEAR PROTRUSIONS

The rarest of all nuclear protrusions (6 per cent of fifty spinal columns examined by Batts), and probably least important from a clinical standpoint, is the anterior protrusion of the intervertebral disc Several of our specimens showed an anterior bulging of the whole disc substance, but this can hardly be classifiable as protrusion or prolapse of the disc One specimen, from a woman, sixty-eight years old, shows very clearly an actual anterior protrusion of nuclear material from the lumbosacral intervertebral disc (Fig 7,*a* and *b*). The protruded substance streams over the anterior edge of the first sacral segment and dissects along the border between the ligament and the bone for one centimeter or so There is an associated break in the anterior longitudinal ligament, but this may be an artefact The protrusion consists chiefly of desiccated nuclear material, with much reaction in the form of new cartilage nests along the border There is an attempt at penetration into the marrow spaces, which is almost an erosion; and there is evidence of invasion of granulation tissue into the prolapsed material

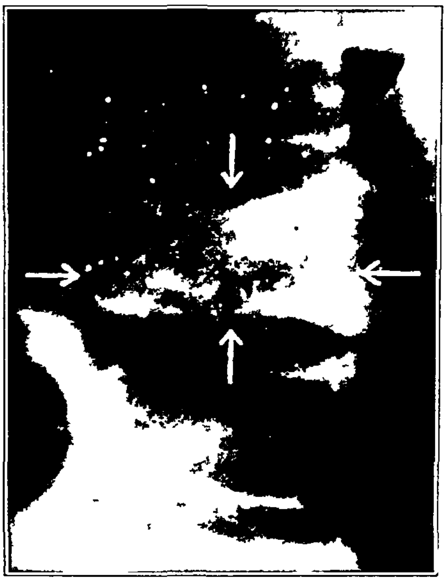

FIG 8-B

Roentgenogram of the vertebra shown in Fig 8-A The arrows indicate the affected vertebra

The disc itself is severely degenerated, with very few normal cells remaining. There is a large horizontal cavity. No actual thinning is observed. The roentgenogram is interesting,—the anterior bulge of the annulus can be seen, beneath which is the actual rup-

tured nuclear material; it appears to have eroded into the anterior superior margin of the vertebral body.

G. POSTERIOR NUCLEAR PROTRUSIONS

Posterior protrusion of the intervertebral disc is an entity which was recognized as early as 1858, when von Luschka first discovered it. Goldthwait, in 1911, described in detail a case of posterior protrusion of a disc. Schmorl, in 1929, rediscovered posterior protrusions. Bradford and Spurling, in their monograph on intervertebral discs, gave credit to Mixter and Barr for presenting the first adequate description of the full clinical picture of protruded discs.

This study does not deal with gross specimens, as seen at necropsy. However, by microscopic study several discs were observed which clearly indicated that there had been rupture of the posterior portion of the annulus fibrosus with herniation of disc tissue into the spinal canal.

Trauma is thought to be the cause of posterior protrusion, with degeneration of the annulus as a predisposing factor. Beadle stated that posterior protrusion of the disc is never encountered when the patient is less than thirty years of age, and that it rarely causes symptoms. Both these statements have been proved incorrect in the light of present experience. In many cases in which acute posterior protrusion of a disc is encountered clinically, the patient is less than thirty years of age. The incidence of posterior protrusion has been put by Beadle at 15.2 per cent. of all spinal columns examined at necropsy. Batts found 16 per cent. of posterior rupture in an examination of fifty spinal columns. Horwitz, examining seventy-five cadavera, found that fifty showed posterior bulging, but that only four had evidence of posterolateral protrusion. Love and Walsh have found that 96 per cent. of protrusions occur in the lumbar region.

Seven of eighty-eight specimens (8 per cent.) examined microscopically in this study showed definite evidence of posterior protrusion,—that is, a rupture of the posterior portion of the annulus fibrosus with a loss of nuclear substance. It should be remembered that all ages are represented in this study, and that only lumbosacral discs were examined. The actual percentage of protrusion is undoubtedly higher, for the sections in this study were roughly midsagittal, and it is probable that many lateral protrusions were missed.

Figure 5,*a* shows a posterior protrusion in a thinned disc. Either the annulus fibrosus ruptures completely, or most of the fibers rupture, leaving intact only the outermost bands. These bands are seen to bulge markedly into the spinal canal. Through the opening so created are pushed the nucleus pulposus and fragments of the remaining annulus. This material shows dehydration and necrosis. In addition, hyperplasia of the cartilage cells occurs, so that the older protrusions are actually made up chiefly of cartilage. Bradford and Spurling stated that invasion of the disc by fibrous tissue and blood vessels is rare. Three of the seven cases in the present study showed invasion by blood vessels and fibrous tissue through the torn annulus into the disc substance. Calcification and ossification of the protruded material may occur. There was evidence of bone formation in one of the specimens. Deucher and Love, studying protrusions removed at operation, found much evidence of degeneration. Thirty-two per cent. of their specimens showed advanced degenerative change, most of it in the sixth decade.

Accompanying posterior protrusion of a disc is an actual loss of disc substance, and thinning occurs in many cases. Love and Camp, in a series of cases in which laminectomy was performed, found only a small percentage to have narrowing of the disc at the same disc level as the posterior protrusion. There was often narrowing at some other site than that of the protrusion. In two of the cases in the present study there was gross evidence of thinning. Between the two cartilaginous plates there was a cavity, created by the loss of nuclear material. Usually some nuclear material remains in the disc, and in most cases, is found on microscopic examination to be necrotic and pigmented.

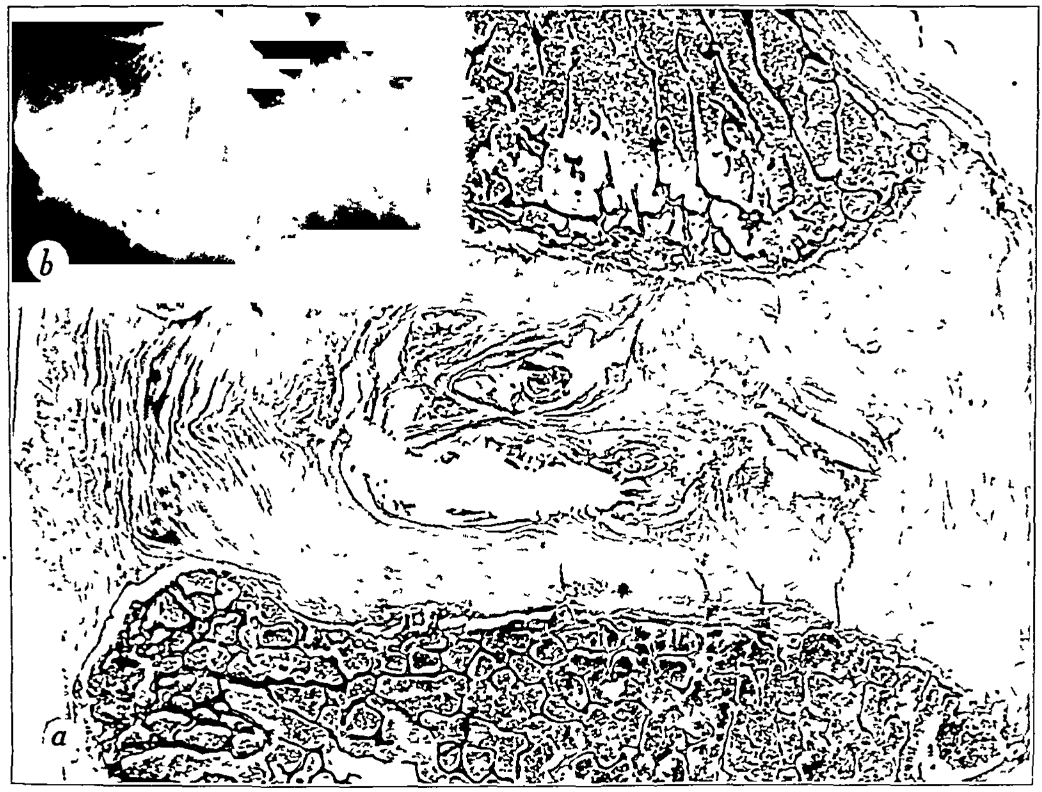

FIG 9

Calcified nucleus pulposus of a woman, aged seventy-one years. *a* Section (× 4) The calcium salts have been dissolved during preparation of the section, leaving space *b*. Roentgenogram

H. CALCIFIED NUCLEUS PULPOSUS

Deposition of calcium in the intervertebral disc takes several forms. Among older people there are large deposits beneath the cartilaginous plate; small nodes of calcium may be deposited in the plate itself or in the annulus; the nucleus itself may become completely calcified; or the entire disc may undergo calcification.

Calcification of the nucleus is recognized as a definite entity, not to be confused with other types of calcification. Calvé and Galland described it in 1922. The entire nucleus is converted into a mass of calcium salt. Microscopically the calcium is not seen, having been dissolved during preparation of the slide. In its place are strands of an amorphous residue.

One case of calcified nucleus pulposus was found in this study (Fig. 9). It showed the rest of the disc to be relatively intact for the age of seventy-one years, and there was no evidence of thinning. The roentgenogram revealed homogeneous, oval masses, congregated in the region of the nucleus; several of these masses were grouped together to form a cast of the nucleus pulposus.

Clinically, cases of calcification of the nucleus are important from only a differential viewpoint. Calvé and Galland stated that it is sometimes confused with Pott's disease. In Beadle's opinion, it may be mistaken for gouty deposits of uric acid.

I. INVASION BY INFECTION

The intervertebral disc is sometimes involved in infection. This is probably always a secondary involvement, the spread of infection coming either from the adjacent vertebrae through breaks in the cartilaginous plate, or down the longitudinal ligaments, or via the bloodstream. It has usually been thought that tuberculosis enters the disc from the ad-

jacent vertebrae. Cohn has recently shown that involvement of the disc commences early, usually by spread of the infection by way of the longitudinal ligaments. The annulus and nucleus pulposus are destroyed early. It seems probable that certain blood-borne infections may settle in the intervertebral discs, involving them before attacking the adjacent vertebrae. Brucellosis falls within this group. There are other types of infection involving the discs, in which the etiological agent cannot be identified, as pointed out by Ghormley, Bickel, and Dickson; and, as in brucellosis, thinning of the disc is an early sign of such infection. Reactive changes such as erosion and sclerosis adjacent to the disc sometimes occur.

Cases of infection involving the lumbar disc were not found in the routine examination during this study, but one of a man, aged sixty-five years, has been included in this report (Fig. 10). Necropsy showed vertebral osteomyelitis (staphylococcus aureus), secondary to extension down the psoas muscle from a subdiaphragmatic abscess. The microscopic section showed only about a fourth of the cartilaginous plate, the rest having been destroyed. There were no remains of annulus or nucleus, the space formerly occupied by them having been filled with exudate. The marrow spaces were invaded by polymorphonuclear leukocytes, plasma cells, and lymphocytes. The infection of the disc in this instance was clearly secondary to infection either in the bone or down the longitudinal ligaments.

Fig. 10
Vertebral osteomyelitis, involving an intervertebral disc of a man, aged sixty-five years.

J. INVASION BY A MALIGNANT LESION

According to Beadle, the intervertebral discs are very resistant to invasion by malignant lesions, even more than to infection. Various types of malignant lesions, sarcoma and carcinoma, primary and secondary, have been seen to involve almost all of the adjacent vertebrae, and still not to invade the disc. This is due to the resistive power of the cartilaginous plate.

Our study included only one case of malignant lesion,—a metastatic lesion in a vertebra from a carcinoma of the prostate (Figs. 8-A and 8-B). The body of the vertebra was rather completely infiltrated with malignant cells. There was a mild collapse of the body, as is seen in osteoporosis. One disc was touched in several places by invading carcinoma, but the cartilaginous plate was intact. On the other end of the vertebra, the opposite disc had protruded through a very small defect in the cartilaginous plate, and formed a large Schmorl body, extending halfway into the body of the vertebra. Beadle stated that most prolapses of this type are of the wide, oval variety, with much cartilage destroyed. This was not the case in our specimen, as the prolapse had a narrow neck and a round, smooth body. The prolapse contained chiefly nuclear material, severely degenerated. There was little attempt at proliferation of cartilage. Around the prolapse, between the metastatic carcinoma and the prolapse, was a clear zone of oedematous granulation tissue. No attempt of the carcinoma to invade this prolapse was noted, nor was any attempt at invasion of the discs by the carcinoma seen.

The roentgenographic appearance was characteristic of metastatic malignant lesions of the osteoblastic type. The metastatic lesions appeared more calcified than the adjacent bone, and thus more resistant to roentgen rays. Interestingly, the Schmorl body cannot be clearly seen in the roentgenogram, because of lack of reaction in the form of bone sclerosis surrounding it.

SUMMARY

The pathological changes studied in this series include hypertrophic arthritis, nuclear expansions, ballooned discs, thinned discs, nuclear herniations into the vertebrae (Schmorl bodies), anterior and posterior nuclear protrusions, calcification of the nucleus pulposus, infections of the disc, and invasion by malignant tumors.

Nuclear expansions are for the most part physiological, and not pathological; whereas ballooned discs are found almost entirely in the disease entity known as senile osteoporosis of the spinal column.

There are two types of thinned discs: one in which the cartilaginous plate and annulus are intact, the thinning being due to desiccation and necrosis of the nucleus pulposus, and the other type in which the annulus is ruptured, or the cartilaginous plate contains many defects. Dehydration is essentially the cause of thinning in both types.

Intraspongy nuclear herniations or Schmorl bodies are for the most part asymptomatic. Anterior nuclear protrusions are rare and of little clinical interest, whereas posterior nuclear protrusions are of great clinical importance. Eight per cent. of the specimens showed evidence of posterior nuclear protrusions.

Calcification of the nucleus pulposus is a definite entity. However, it is of no clinical significance.

Infection of the disc, resulting in early destruction of the annulus and nucleus, is recognized. The infection is usually blood-borne, and it may be primary or secondary to involvement of the vertebral body. The only example in this group was of infection of the disc, secondary to involvement of the vertebra.

Invasion of the disc space by a malignant lesion is rarely found. Only one example was observed in this series, and in this case no real invasion of the cartilage was seen.

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THE INTERVERTEBRAL FORAMINOTOMY FOR RELIEF OF SCIATIC PAIN

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Low-back pain with sciatic radiation has long been a problem to the orthopaedic surgeon. Pain in part of the sciatic-nerve distribution is frequently caused by some impinging mass squeezing or stretching one or more nerve roots. Herniation of the nucleus pulposus explains a large number of these cases. Our intention is: (1) to contribute toward the understanding of another large group,—those cases where there is impingement upon the nerve root within the intervertebral foramen; (2) to show what the various causes for such impingement may be; and (3) to outline the operative decompression.

The indications for simple laminectomy to relieve pain due to nerve-root pressure are generally known and accepted. However, during our surgical explorations seeking the oppressing medium, we encountered instances when there had been no hypertrophy of the ligamentum flavum, no concealed disc, and no herniation of the disc. In fact, no impinging mass could be found even after thorough visualization and palpation of the vertebral canal had been made. We were not alone in failing to find the lesion upon performing simple laminectomy. Hyndman, Steindler, and Wolkin reported that a small percentage of their patients, who presented definite symptoms and signs of root compression, including a negative Achilles tendon reflex, showed no herniated disc, concealed or otherwise.

About four years ago it occurred to the senior author (H.B.) that a complete exploration of the nerve root was not actually performed until that portion passing through the intervertebral foramen had been examined. Since that time we have employed a surgical procedure, which we have designated "intervertebral foraminotomy".

Our decision to make this exploration finds substantiation in the work of other investigators, among whom may be mentioned Nachlas, Oppenheimer, Hanflig, Breck and Basom, Horwitz and Smith, Bromer, Larmon, and Magnuson. The intervertebral foramen is a bone-lined duct the dimensions of which are only slightly altered under normal conditions. Any encroachment upon this space, beyond the physiological, will result in pressure upon the soft tissues contained within it. We wish to stress that examination of the vertebral canal by simple laminectomy is frequently not sufficient when one is looking for a cause of pressure upon a nerve root.

It is our common practice, when exploring the vertebral canal, to examine the ostium of the intervertebral foramen. When necessary, we have removed that portion of the articular process which overhung and obscured our visualization of the ostium. In many instances, that manoeuvre has uncovered small protrusions of the intervertebral disc. However, we do not consider that procedure to be an intervertebral foraminotomy. The entire foramen can be explored only by removing all or a large part of both articular processes.

The surgical technique employed is largely that reported by Williams and Yglesias, Ghormley, and Mitchell as facetectomy. We have employed the phrase "intervertebral foraminotomy" because it describes more aptly the surgery performed. A closed canal is actually converted into an open trough. The exposure of the vertebral column is carried out to beyond the articular processes; bleeding is controlled by pressure and electrocautery if necessary. The ligamentum flavum on the affected side is then removed in its entirety. If there is insufficient interlaminar space in which to perform good exploration, adjacent portions of the laminae are removed to increase the space. In order to open the intervertebral foramen, the facets with their articular processes are removed. Both rongeur and osteotome are employed for this removal of bone, which must be done slowly

and carefully, only small pieces being removed with each bite. When the osteotome is employed, the bone involved is always backed up by a suitably sized curette in the hands of the assistant. In that way, bone fragments are not pushed into adjacent soft tissue. The field is kept clear of bone bleeding by suction. Sufficient bone, ligamentum flavum, and capsule are removed to visualize the nerve root along its entire course until it passes into soft tissue. The lesion is removed; operation is completed by placing a small piece of muscle tissue over the exposed nerve root, and fusion is performed, employing the chip fusion described by Briggs and Milligan. The patient is returned to bed, and the postoperative course is that followed routinely for a simple spine fusion.

The senior author has been the responsible surgeon in thirty-five operations where intervertebral foraminotomy has been a part of the surgical procedure. In this group the following lesions were found: (1) diminution of foraminal space, secondary to diminution of the intervertebral disc space; (2) hypertrophic lipping of the posterior periphery of the vertebral bodies (this hypertrophy was often cartilaginous, and did not show on roentgenograms); (3) herniation of the intervertebral disc into the intervertebral foraminal space; (4) nuclear material impacted within the foramen, which seemed to have migrated from some distant point of herniation.

In the first condition, diminution of the foraminal space, secondary to diminution of the intervertebral disc space, our series includes twenty-two cases. In these, simple unroofing of the intervertebral foramen has been found to be sufficient; the nerve root lies in a space of greater dimensions. Adequate space has been provided by the removal of the articular processes, and in some cases a portion of the pedicle, so that a trough was formed. Occasionally the nerve root was bound down by adhesions. These were gently released, and the nerve root was seen to lie free before the operation was completed.

One such case is of a man aged forty-eight. Seven years earlier he had undergone surgery at this Hospital for removal of a ruptured intervertebral disc. At that operation the herniation was found and removed; lumbosacral fusion, employing a tibial graft, completed the operation. The patient remained free from symptoms for seven years. Six weeks prior to his latest admission to the Hospital, there was sudden return of the original unilateral sciatic pain. This pain became increasingly severe. Neither manipulation, bed rest, nor brace immobilization gave any relief. Only large doses of narcotics were of any avail. Roentgenogram showed a complete collapse of the fifth lumbar disc space, as compared to a reported diminution of disc space seven years earlier. At operation we found that the graft had joined the involved vertebrae only by fibrous union. The bodies of the fifth lumbar and first sacral vertebrae were contiguous. The left fifth lumbar nerve root was oedematous, hyperaemic, and immobile. Intervertebral foraminotomy was performed, and adhesions binding the nerve root were broken. Within eight hours after the operation, there was considerable diminution of sciatic pain, and after forty-eight hours all narcotics were discontinued. A sense of weakness of the involved limb is present three months after the operation, but the patient has returned to work.

In those cases, seven in number, where hypertrophic lipping of the posterior periphery of the bodies existed, a second step was added to the unroofing procedure. We have gently lifted the nerve root free of its bed, and removed the hypertrophic portion plus a part of the parent body, with a small osteotome or curette. In our experience, this manipulation has not inflicted trauma to the nerve root leaving more than transitory symptoms.

The five cases which displayed frank herniation of the intervertebral disc within the confines of the intervertebral foramen were treated in the routine manner for such protrusions. The herniation was incised, and nuclear material was removed with curette and forceps. One such case displayed an interesting herniation which we should not have found without an intervertebral foraminotomy. The bulge in the annulus fibrosus was found to lie at the very periphery of the foramen as a posterolateral herniation. The bulging mass forced the nerve root to ride cephalad, squeezing it between the herniation and the pedicle of the fifth lumbar vertebra.

Free nuclear material impacted within the intervertebral foramen was found in one case. Subsequent diligent search revealed the original rent in the annulus fibrosus. The

point of rupture was just lateral to the posterior mid-line, about one inch distant from the loose nuclear fragment. Again we believe that this impinging mass could not have been recovered safely other than by foraminotomy. The patient immediately after surgery showed dramatic relief from intense sciatic pain. Prior to surgery, he had undergone all forms of conservative therapy, which gave relief only when accompanied by narcotics. Buck's bilateral traction gave relief only while traction was being exerted.

A small group of our cases, eight in number, had the intervertebral foraminotomy performed bilaterally. These patients complained of bilateral sciatic pain. They displayed a marked collapse of the intervertebral disc space, with simultaneous diminution of the foraminal space on both sides. Of this group, one patient had previously been subjected to mid-line laminectomies, in two separate operations, of the fourth and fifth lumbar vertebrae. Bilateral intervertebral foraminotomies at the lumbosacral junction gave immediate relief from sciatic pain, with persistent relief since operation. The patient's only complaint at present is that "pressure over the hole (laminectomy) in the spine is somewhat painful".

Our series of cases included intervertebral foraminotomies of the fourth as well as of the fifth foramen. When surgery involved the fourth space, fusion was performed to bridge only the fourth and fifth lumbar vertebrae. In this series, there is also one foraminotomy performed at the left side of the second lumbar intervertebral foramen.

This patient complained of pain radiating across the left mid-back and around to the abdomen. He had received a compression fracture of the body of the second lumbar vertebra, several years earlier. The radiating pain was of comparatively recent onset. Mid-line laminectomy with section of the sensory fibers of the second lumbar nerve root had failed to give relief for more than several months. We performed an intervertebral foraminotomy at the second lumbar space, exposed the nerve root, and permitted it to lie free. The patient has shown a decreasing degree of pain since that time, and is now symptom free.

The patients of this series have been seen regularly at intervals of six weeks to three months. The postoperative span for the individuals ranges from three months to four years. Relief from sciatic pain has been complete in all but three cases. One of this group insisted almost immediately after the operation that she had not been relieved. Undoubtedly the sciatica in this individual was not due to pressure upon the nerve root, with which we had been dealing. The other two are similarly unsolved problems.

It may be said that spine fusion, weeks of bed rest, use of a brace, or perhaps factors other than an intervertebral foraminotomy, gave the relief from pain. We do not feel that any of these factors are significant; for definite impinging masses were found in those cases in which foraminotomy was performed. Of our patients, 25 per cent. had been previously subjected to spine fusion with or without removal of a herniated disc. All of them had been subjected to long intervals of bed rest, use of a brace, and other conservative measures. All of those patients in whom good results were obtained, volunteered the information that the referred pain was relieved, or considerably reduced, immediately after operation.

We do not feel that the intervertebral foraminotomy has increased the operative risk or degree of complications, as compared to simple spine fusion with simple laminectomy. In our earlier experiences some cases showed slight residual muscle weakness or infrequent flashing pain in sciatic areas, for several days following operation. However, as our technique improved, we found that these evidences of nerve-root traumatization decreased in number. Our main regret is that the follow-up period is relatively short for many of the cases; we are waiting impatiently for the passage of the two-year, five-year, and ten-year periods.

Within our experience, we have formulated three indications for an intervertebral foraminotomy. They are as follows: (1) when simple laminectomy, with complete exploration of the accessible nerve root within the neural canal, has failed to reveal an imping-

ing mass; (2) complete or considerable collapse of the intervertebral disc space, with or without hypertrophic lipping as seen on the roentgenogram; (3) previous spine surgery, with or without fusion, which has failed to relieve the sciatic pain.

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CHRONIC MELIOIDOSIS

A Case Showing Multiple Lesions of Bones, Joints, and Lungs

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Melioidosis is an infective disease occurring in Burma, Ceylon, French Indo-China, the Dutch East Indies, Malaya, and Siam. Several hundred cases have been recorded since the original description of the disease by Whitmore and Krishnaswami in 1912. In the vast majority, the disease has been acute, with symptoms simulating cholera or enteric fever, and has proved fatal from septicaemia within a few days or weeks.[1,7,8,10] At autopsy, the commonest findings recorded in such cases have been areas of consolidation and small abscesses in the lungs, and abscesses or areas of caseation in the spleen, liver, and kidneys. Manson-Bahr records cases in which recovery from the primary attack was followed by a fatal septicaemia, and in which pulmonary lesions resembling tuberculosis were found at autopsy.

The chronic form of this disease is far less common. Five cases have been found in the literature, only two of them in Europeans. However, with the employment of large Allied forces in Far Eastern areas, where the infection is endemic, early recognition of its symptoms is of vital importance.

Melioidosis is recognized as a disease of rodents and man; it is generally assumed that infection in man is acquired from infected rodents, possibly by contaminated food or water supplies. The causative organism was named bacillus whitmori by Stanton and Fletcher in 1921, but was assigned to the pfeifferella group of bacteria by Topley and Wilson, and is now known as pfeifferella whitmori or malleomyces pseudomallei.

The following summary of five chronic cases is included in spite of previous appearance in the literature, because it is felt that some readers of *The Journal* may not have access to the original reports.

Case 1. An acute illness at onset in a native adult was followed by discharging sinuses, in both feet, which led to necrotic bone. Two years after the onset, the sinuses were still discharging, but the causative organism could no longer be isolated, and the general health of the patient was good.[11]

Case 2. An acute illness at onset in a native adult was followed by a discharging sinus over one lateral malleolus, from which pfeifferella whitmori was recovered repeatedly. Complete recovery ensued five months after the onset.[11]

Case 3. The patient was a native adult. An acute illness was followed by chronic involvement of the genito-urinary tract, and terminated in complete recovery.[9]

Case 4. A native infant had had no acute illness, but abscesses developed insidiously over one metacarpal and one parietal bone, with roentgenographic evidence of osteitis of the metacarpal. Complete recovery ensued after six months.[9]

Case 5. In a British soldier serving in Malaya, the history of onset was confused by a concurrent gonococcal infection which may have accounted for some of the earliest joint manifestations. Destructive bone lesions occurred in the bodies of the fourth and eighth thoracic vertebrae, associated with a paravertebral abscess, and there was also osteitis of one frontal bone and of one fibular malleolus, with abscess formation. The disease had not healed when the case was recorded two to three years after onset.[3]

Four of these five patients had one or more bone lesions, and three had had an acute illness at the onset. In each case, the diagnosis was made by identification of the causative organism.

The following is a further report of a case already presented by the author.[6] It is apparently the second to be recorded in a European, which fact would give rise to the theory

that Europeans have a greater natural resistance to the organism than natives. Although the first case was of considerable duration, that to be described presents by far the longest illness yet reported in this disease; the multiplicity of lesions also appears unique. Its importance lies, however, not so much in its rarity, but in its singular resemblance to tuberculosis. Since this case was incorrectly diagnosed for nearly three years, despite repeated bacteriological investigations, it seems highly probable that similar cases have remained — and may remain — unrecognized.

CASE REPORT

In July 1940, the patient, thirty-three years of age, a regular soldier in the British Army, was admitted to a hospital in Singapore, with a complaint of pain in the lumbosacral region, radiating down the thighs, especially the right. His symptoms had begun insidiously one month before admission. There was no history of tuberculosis or similar chronic disease in his family or contacts. Positive findings in the past history included empyema on the left side in early childhood, without sequelae, and an appendectomy at fifteen years of age. He had served in India from 1931 to 1937, during which period he had had attacks of dysentery, malaria, and tonsillitis. He had been in Singapore since 1938. In February 1940, he had had urticaria and swelling of finger and toe joints, which had disappeared after two months, following tonsillectomy and the administration of an autogenous vaccine.

Examination on admission showed no abnormal physical signs, except stiffness of the lumbar spine and enlarged rubbery inguinal lymph nodes, which on biopsy were negative. Roentgenograms of the lumbar spine and sacro-iliac joints showed no abnormality. The patient had an irregular pyrexia and heavy night sweats.

In August, flexor spasm of the right hip and slight wasting of the right buttock were noticed. At this time, the laboratory findings were:

Red blood cells,—5,800,000;
  Hemoglobin,—66 per cent.;
White blood cells,—12,000;
  Polymorphonuclear neutrophils,—72 per cent.;
  Lymphocytes,— 24 per cent.;
  Large monocytes,— 1 per cent.;
  Eosinophils,— 3 per cent.;
Repeated blood cultures,—negative;
Wassermann reaction,—negative;
Widal reaction,—positive only in very low titre;
Stools,—negative for ova, cysts, and occult blood;
Urine,—negative except for a few leukocytes.

During the next few months, the patient's general condition deteriorated. His fever subsided temporarily with the administration of sulfapyridine. In October, his sedimentation rate was sixty millimeters per hour, but fell to twenty millimeters (method not stated) during the following month. A tentative diagnosis of ankylosing spondylitis was made.

In January 1941, a lumbosacral abscess developed, culture of which was negative. During the following month, an abscess developed in the right sacro-iliac region, from which vibrio alkaligenes was cultured. Injected guinea pigs died of a virulent septicaemia, and were reported negative for tuberculosis. The patient was kept recumbent, and showed slight improvement in his general condition.

The patient was transferred to a hospital in India where, in June, roentgenograms revealed slight rarefaction and loss of definition in the lower part of the right sacro-iliac joint. The Wassermann, Kahn, and Widal reactions were again negative, and the Weil-Felix reaction was positive only in low dilution against bacillus proteus O-X-19, O-X-2, and O-X-K. In July, bilateral sacro-iliac abscesses developed, which were sterile on aspiration, but from the drainage of which staphylococci were grown. Injected guinea pigs were reported to have died of staphylococcus septicaemia. The diagnosis was now changed to tuberculous sacro-iliac arthritis, with secondary infection.

In August, following roentgenograms which showed destruction of the right sacro-iliac joint, a bilateral hip spica cast was applied.

In May 1942, roentgenograms showed collapse of the body of the eighth thoracic vertebra with a large paravertebral abscess and no narrowing of the intervertebral discs, slight sclerosis of the adjacent vertebral bodies at the lumbosacral joint with narrowing of the disc space, extensive infiltration at the base of the right lung, bilateral hilar enlargement, and bilateral apical pleural thickening. The laboratory findings at this time were:

Red blood cells,—5,400,000;
  Hemoglobin,—60 per cent.;

White blood cells,—6,400;
  Polymorphonuclear neutrophils,—52 per cent.;
  Lymphocytes,— 45 per cent.;
  Large monocytes,— 3 per cent.;
Sedimentation rate,—110 millimeters per hour (Westergren);
Urine,—negative;
Repeated sputum examinations,—negative for tuberculosis.

The patient, recumbent but unsplinted, was now transferred to a hospital in South Africa. He continued to have low backache, pain in the right lower extremity, and intermittent pyrexia. He had an angular kyphosis at the eighth thoracic segment, and a deformity and pain on motion at the right hip. There was poor expansion of the right side of the chest, with bronchial breathing over the lower lobe and dullness of the middle lobe. The diagnosis was multiple tuberculous arthritis and tuberculous bronchopneumonia. In July 1942, a right psoas abscess developed, culture of which showed numerous gram-negative bacilli, and, in August, there was a single large hemorrhage from the intestine, the cause of which was not discovered. In October 1942, roentgenograms showed destruction of the right femoral head and of the acetabular roof with adduction and dislocation, destructive changes in the right sacro-iliac joint, increased irregularity of the surfaces at the lumbosacral junction, increased wedging of the eighth thoracic vertebra, slight clearing of the right lung, and slight mottling of the left lung. The patient continued to have fever in irregular attacks, and a pulse rate which varied in proportion to his temperature. The right lower extremity was placed in traction, to correct the adduction deformity of the hip. In December, the hip was manipulated into an improved position and immobilized in a plaster cast. In January 1943, a cold abscess of the right buttock developed and slowly subsided.

Shortly after the author had taken over the case in April 1943, a large abscess of the anterior aspect of the right thigh was discovered when the cast was changed. Aspiration yielded thin, diffusely blood-stained pus from which pfeifferella whitmori was isolated for the first time by my colleague, Major M. H. Finlayson. Agglutination was positive at a dilution of 1 to 500. Negative laboratory examinations at this time included the sputum; urine; culture of urine and faeces for pfeifferella whitmori; blood culture; Wassermann, Kahn, and gonococcal complement-fixation tests; and agglutination tests against organisms of the enteric, brucella, and proteus groups.

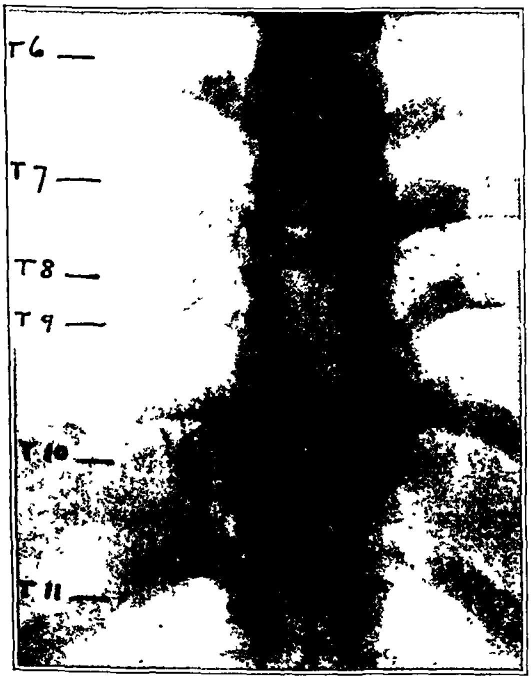

Fig. 1-A

May 1943. Anteroposterior view of the lower thoracic spine, showing the collapsed eighth thoracic vertebra, the paravertebral abscess, and slight narrowing of the disc between the eleventh and twelfth vertebrae. (*Reproduced by courtesy of Journal of the Royal Army Medical Corps.*)

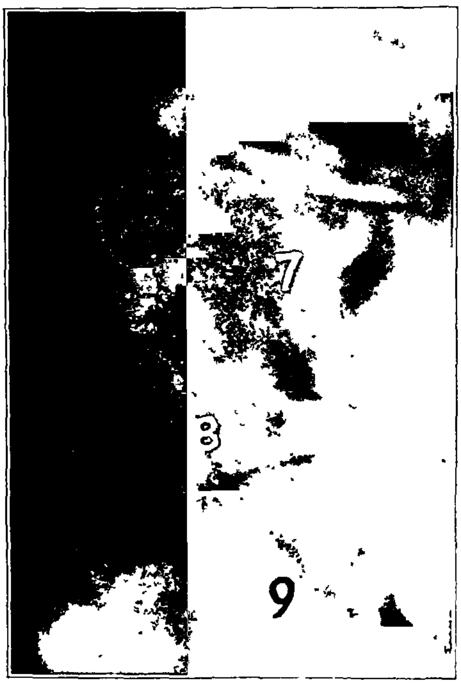

Fig. 1-B

May 1943. Lateral view of the lower mid-thoracic vertebrae, showing wedge-shaped collapse of the body of the eighth vertebra with clear definition of both adjacent intervertebral discs, which are of practically normal width. (*Reproduced by courtesy of Journal of the Royal Army Medical Corps.*)

FIG 2

May 1913 Anteroposterior view of the right hip joint The femoral head is dislocated and almost entirely destroyed; and the acetabular roof has also been involved in the destructive process. Despite the roentgenographic appearance suggesting bony fusion, ankylosis was clinically unsound. (*Reproduced by courtesy of Journal of the Royal Army Medical Corps.*)

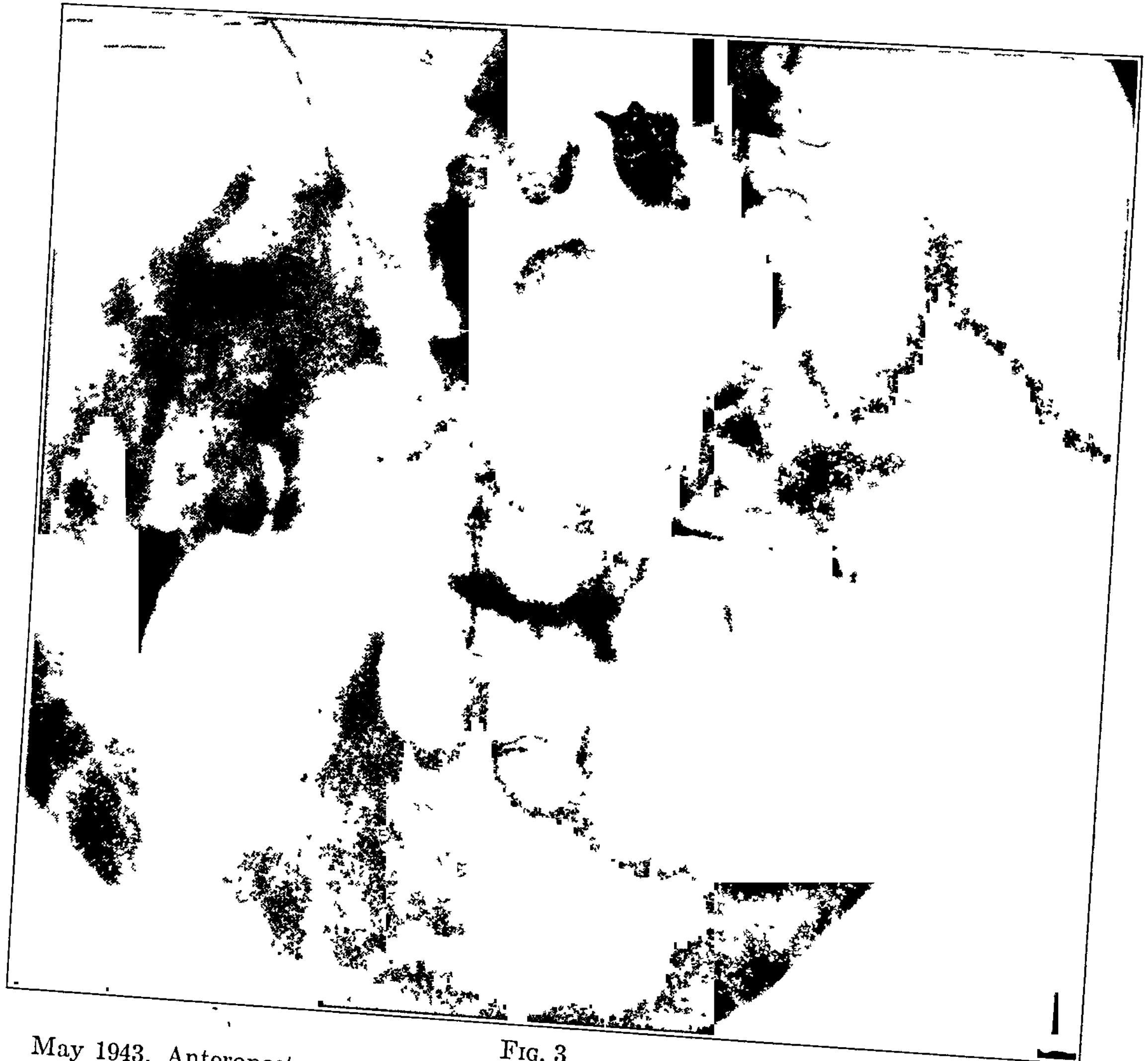

FIG. 3

May 1943. Anteroposterior view of the sacro-iliac joints. The appearances of bone destruction in the right joint were constant in several roentgenograms taken at different dates, and are, therefore, not due to overlying gas shadows. There is loss of definition of the joint surfaces and apparent obliteration of the joint space near its center. Similar changes are suggested on the left side, where fusion appears to be taking place. Patchy areas of sclerosis and of decalcification are also visible. (*Reproduced by courtesy of Journal of the Royal Army Medical Corps*)

Fig. 4

May 1943. Lateral view of the lumbosacral joint, showing narrowing and loss of definition of the joint space. Extensive decalcification prevented more distinct roentgenography.

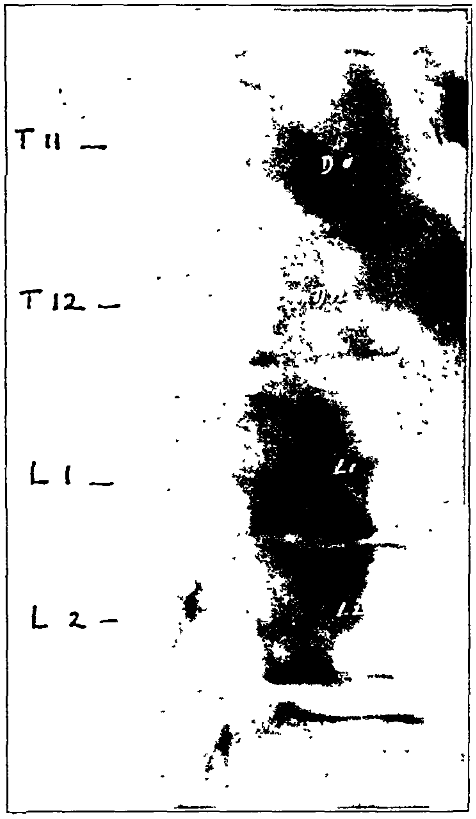

Fig. 5

February 1944. Lateral view of the thoracolumbar spine, showing narrowing of the discs, without bone destruction, between the eleventh and twelfth thoracic vertebrae, and between the first and second lumbar vertebrae; the twelfth disc appears slightly widened anteriorly.

The patient was treated with autogenous vaccine, by hypodermic injections of 10,000,000 dead organisms; the dose was increased fairly rapidly at biweekly and later at weekly intervals. Several additional abscesses and sinuses developed about the sacrum and groin during the next month, characterized by blood-stained, "anchovy-sauce pus" which, on culture, showed pfeifferella whitmori. Roentgenograms also showed narrowing of the disc space between the eleventh and twelfth thoracic vertebrae. After the dose of vaccine had been increased to 400,000,000, each injection was followed by increased fever a few hours after the inoculation and a slight local reaction at the site. The patient had a microcytic anaemia, and continued drainage from the thigh abscess, but showed general improvement. As Finlayson had shown experimentally that urea was lethal to pfeifferella whitmori *in vitro*, a saturated solution of urea was used for irrigating the persistent sinus in the thigh, but this had no appreciable effect. Sulfadiazine then became available, and was given with apparent beneficial effect on the fever and general condition. A total of forty-five grams of the drug was administered over a period of four weeks without harmful effects. Vaccine therapy was stopped in January 1944, after a maximum weekly dose of 2,500,000,000 organisms had been reached.

By April 1944, all of the sinus tracts had healed. The patient was gaining weight, and had been completely afebrile for three months. His hemoglobin had increased to 97 per cent., and his sedimentation rate had fallen to twenty-six millimeters per hour (Wintrobe). Roentgenograms in February 1944 showed narrowing of the disc space between the first and second lumbar vertebrae, while the chest appeared normal and the lesions in other areas were unchanged. As there had been little sign of spontaneous fusion of the hip, it was thought that arthrodesis would be necessary later. The prognosis was considered favorable for recovery.

Bacteriological Findings

A detailed account of the bacteriological findings in this case has been published previously.[2] I am indebted to Major Finlayson for the following summary.

Morphology and Staining: The organism is a gram-negative, non-sporing, motile bacillus, measuring about one-half to two micra, without evidence of capsule formation. It shows polar staining, but is rather poorly stained by the simple aniline dyes, Neisser's, Albert's and Leishman's stains. Good differentiation was obtained by staining with dilute carbolfuchsin and counter-staining with dilute methylene blue; this method showed red granules on the blue background of the bacillus. In the tissues of inoculated animals, the bacilli were well demonstrated by carbolthionin, and appeared longer and narrower than on culture, sometimes showing short chain formation.

Cultural Characteristics: On blood agar, the organism produced a fine growth after twenty-four hours' incubation, becoming abundant, smooth, gray, and glistening after seventy-two hours' incubation. The organism was also grown in nutrient broth, nutrient gelatine, Loeffler's serum, milk, and McConkey's agar. It fermented glucose without gas formation; failed to ferment lactose, dulcite, saccharose, and mannite; decolorized Andrade's indicator after forty-eight hours' incubation; formed no indole in peptone water; and did not grow on ordinary media under anaerobic conditions.

Animal Experiments: Intraperitoneal injection of 0.5 of a cubic centimeter of a twenty-four-hour broth culture killed a guinea pig in thirty hours, and produced a copious, glairy, peritoneal exudate from which pfeifferella whitmori was grown. The infection was widely disseminated, and caused many visceral lesions. Similar effects followed the injection of mice.

Serological Reactions: Agglutination tests were positive with the patient's serum at a dilution of 1 to 500; were negative with two normal sera at a dilution of 1 to 25, and were positive with the sera of several patients suffering from proved chronic pulmonary tuberculosis in dilutions up to 1 to 50.

Conclusions: Except for its acid-fast properties, the general characteristics of this strain resemble in every respect those described as pfeifferella whitmori by Stanton and Fletcher, and by Topley and Wilson.

DISCUSSION

In retrospect, it is possible to criticize the earlier diagnosis of tuberculosis. The persistent pyrexia at the onset of the disease, despite complete rest, with abscesses developing seven months later, but with roentgenographic changes appearing only after a further lapse of five months, should have been viewed with suspicion. Also atypical was the wedge-shaped collapse of a single thoracic vertebra, without appreciable narrowing of the adjacent intervertebral discs or involvement of neighboring segments. The anomalous bacteriological findings in earlier specimens of pus suggest that pfeifferella whitmori (or malleomyces pseudomallei) may have been present, but had escaped detection. Repeated failure to find bacillus tuberculosis in the sputum had not been explained, but the pulmonary lesions had been regarded as typical of tuberculosis clinically and roentgenographically. This is the only known chronic case showing pulmonary lesions.

The right sacro-iliac lesion may have started either as arthritis, or as juxta-articular osteitis. The extensive destruction of the upper end of the femur suggests that the hip lesion began as an osteitis, and the lesion of the eighth thoracic vertebra was obviously an osteitis. On the other hand, there appears to have been no bone destruction associated with the lesions between the eleventh and twelfth thoracic and between the first and second lumbar vertebrae, both of which are definitely attributable to melioidosis, since earlier roentgenograms of these regions were normal. The lumbosacral lesion appears to have a similar pathology. Thus it seems that some of the lesions primarily involved bone and others cartilage. Much of the patient's improvement may be attributed to the combination of autogenous vaccine and sulfadiazine therapy. While the latter was perhaps more dramatic in effect, it was first employed at a time when the patient might have been expected to improve because of better drainage. Furthermore, general improvement had been noted with vaccine therapy before the use of sulfadiazine, and improvement continued with vaccine therapy after the sulfadiazine was stopped. Therefore, it seems that these agents, used in combination, are valuable. Urea, despite the experimental *in vitro* evidence, was of no apparent value, but this may have been due to the impossibility of achieving adequate contact between the urea and the osteo-articular infection.

An important principle in the treatment of melioidosis is that the abscesses, unlike those of tuberculosis, should be drained early and adequately. Abscess formation was ac-

companied on each occasion by a deterioration of the general condition, which improved following the institution of adequate drainage. Imperfect drainage was always accompanied by the formation of a chronic sinus, but, when good drainage could be established, healing was not unduly delayed.

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THE USE OF SULFONAMIDES IN COMPOUND FRACTURES

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In recent years there have been numerous articles in the medical literature dealing with the treatment of compound fractures. It seems generally agreed that most of the compound fractures occurring in the war zones are best treated by leaving the wounds open. However, in civilian injuries, it is felt by many that, following an immediate irrigation and débridement, suture of the contaminated wound is a logical procedure in selected cases. Such factors as the extent of tissue damage, the amount of gross contamination, the time elapsed since the injury, *et cetera,* are of importance in deciding whether or not this initial suture is advisable. These same factors are of importance in the incidence of infection in these primarily closed wounds. The implantation of one of the sulfonamides in the wound at the time of operation is another factor which possibly influences infection, and for this reason the surgeon might feel safer in closing these wounds primarily.

In this paper we shall attempt to evaluate the use of sulfonamides in compound-fracture wounds treated by primary suture, following débridement and careful irrigation of the wound. We have as the basis for this study two series of cases. In one series, treated from 1933 to 1941, no local or systemic drug was used, and this series will serve as a contrast. In the second series, from 1941 through 1943, one of the sulfonamide drugs was used locally, and in thirty cases was given by mouth postoperatively. It is our purpose to present these cases as comprehensively as possible in order that our series, admittedly not large, may be compared or added to other similar reports. We are limiting the scope of this report to the presence or absence of infection in the soft tissues or bone.

CASES FOR STUDY

This report is based on the records of 166 compound fractures occurring in 164 patients. The records of all compound fractures of the long bones, treated in the New Haven Hospital over a ten-year period, have been examined. Twenty-four of these patients have been omitted from this report, because either they died within a few hours of multiple injuries or shock, or they were treated by packing the wounds open. The only cases selected for this report were those treated by primary suture, following careful débridement and irrigation. Most of these injuries were sustained in automobile accidents, and the patients were brought to the Hospital by ambulance. The period elapsing between the initial injury and the time the patient arrived in the operating room varied from forty minutes to ten hours and forty minutes. One patient had a tiny wound that had been present twenty-four hours. The great majority of the patients, however, reached the operating room in from two to five hours following the accident. The ages of the patients varied from five to eighty-one years.

Table I shows the number and percentage of the various bones involved.

TREATMENT

All of these 164 patients were first admitted to the Emergency Room where they were seen by a doctor immediately. A general examination of the patient was then carried out, and, if shock was either present or impending, measures to control this were taken. The clothes about the wound were then removed and a sterile dressing applied. If the splinting done outside the hospital was not adequate, this was replaced. A prophylactic dose of tetanus antitoxin was given in all cases, and most of the patients received gas-bacillus

TABLE I
LOCATION OF FRACTURES

Bone	Number	Percentage of Total
Humerus	22	13.3
Radius	28	16.8
Ulna	16	9.6
Femur	2	1.2
Tibia	95	57.3
Fibula	3	1.8
Total	166	100.0

antitoxin in addition. After these measures had been completed, roentgenograms were taken, and the patient was sent directly to the operating room.

After satisfactory anaesthesia had been obtained, another sterile dressing was applied to the wound; the extremity was thoroughly cleaned and the dressing was removed. The surgeon then prepared the field about the wound. (During the past three years, soap, alcohol, and tincture of zephiran have been used. In the period before this, soap, benzine, ether, iodine, and alcohol were used.) The surgeon then discarded his gloves and draped the field in the usual manner as for a major procedure, and put on a sterile gown and gloves.

Following excision of the skin edges with a scalpel, thorough débridement and irrigation of the wound were done, from within outward. (Since 1941, it has been a routine procedure to put sulfathiazole powder or sterile sulfanilamide powder throughout the wound.) Closure of the wound was then carried out with interrupted catgut sutures in the deep tissues and silk in the skin. Postoperatively, a dry, sterile dressing has been kept on the wound, in recent years. In the period from 1933 to 1939, it was the practice of a few surgeons to place a tiny rubber drain at one end of the wound; this was removed at the end of twenty-four hours for culture. Some surgeons used alcohol dressings at that time.

Since the use of the sulfonamide drugs began in 1941, the drug has been given orally in many cases for about seven days postoperatively, or for a longer period of time if infection occurred in the wound.

The treatment of the fracture itself varied. In the earlier cases of this series, some fractures were treated with catgut or braided silk to approximate the bone ends. Since 1941, if some internal fixation was indicated, metal screws or plates have been used. Traction or casts have been used routinely as the surgeon deemed advisable in the individual case.

Wound Healing

Rather than dividing these 166 wounds into only two groups, it seemed more informative to place them in four groups, as follows:

1. Cases in which primary healing took place.
2. Cases where separation of skin edges, superficial skin necrosis, or small hematomata occurred.

These three complications of wound healing were difficult to fit into the infected group, because the wounds all healed within a few days or weeks by secondary intention without any definite signs of infection. Likewise, these wounds could not be considered healed by primary intention, even though the skin separation involved only a small portion of the wound.

3. Infected wounds.

This group is, of course, difficult to separate definitely from those cases with a mild osteomyelitis, but we have endeavored to put in this group only those cases in which the infection, as far as we could tell, was limited to the soft tissues.

These wounds all healed without sinus-tract formation or changes suggestive roent-

TABLE II

WOUNDS IN WHICH OSTEOMYELITIS DEVELOPED

Age	Injury	Fracture and Wound	Time to Operating Room	Treatment	Drug	Course	Condition of Wound on Last Visit to Hospital
60	Struck by auto	Tibia. Laceration of ten centimeters, with bone protruding.	Four hours	Irrigation, débridement, suture. Skin sutured under tension. Traction and cast.	None	Skin became necrotic about wound and sutures pulled through. Purulent drainage then began.	Sequestrum removed one year after injury. Wound healed four months later. No recurrence at two years.
20	Struck by auto	Tibia. Large wound with bone protruding.	Three hours, fifty minutes	Irrigation, débridement, suture. Dirty bone rongeured away. Tension sutures used. Traction and cast.	None	Tension sutures pulled through. Purulent drainage began.	Continued to drain pus through sinus for one and one-half years.
39	Struck by auto	Tibia. Large dirty wound.	Four hours	Irrigation, débridement, suture, traction.	None	Purulent drainage.	Drainage through sinus tracts over tibia for four months. Patient then left.
21	Struck by auto	Humerus. Wound four centimeters wide.	Four hours	Irrigation, débridement, suture. Braided silk in bone ends. Traction.	None	Sinus tracts formed. Silk removed from bone at nine weeks, but drainage continued.	A few small sequestra were extruded from time to time. Wound healed in seven months.
41	Struck by auto	Tibia. Large dirty wound containing gravel. Bone protruding.	Three hours	Irrigation, débridement, suture. Traction.	None	Wound infected. Progressive osteomyelitis developed. Amputation done four months after injury.	Stump healed after a period of two years from injury. Re-amputation required for healing.
62	Struck by auto	Tibia. Dirty wound of four inches. Bone protruding.	Two hours and a half	Irrigation, débridement, suture. Plate and cast.	Yes	Wound infected. Plate removed. Continued to drain pus.	Draining from sinus tracts after two years.
51	Struck by auto	Tibia. Large wound.	Six hours	Irrigation, débridement, suture with tension. Traction.	No	Infected and drained pus.	Draining pus from open wound at one and one-half years. One small piece of necrotic bone removed.
62	Struck by auto	Tibia. Dirty wound of eighteen inches.	Four hours	Irrigation, débridement, suture. Traction.	Yes	Infected. Skin sloughed. Bone exposed.	Drained one year, then stopped. Bone exposed. No recurrence after six months. Died of coronary thrombosis.
19	Fall in street	Tibia. Puncture wound by sharp object.	Four hours, fifteen minutes	Irrigation, débridement, suture. Traction.	None	Infected. Wound opened and drained profusely.	Extruding small fragments of bone at nine months.

TABLE III

COMPARISON OF WOUND HEALING IN COMPOUND FRACTURES

	Sulfonamide Therapy		No Sulfonamide Therapy	
	Number	*Per cent.*	*Number*	*Per cent.*
Primary healing	30	71.5	82	66.2
Skin necrosis, separation of skin edges, or hematoma	4	9.5	18	14.5
Soft-tissue infection	6	14.3	17	13.7
Osteomyelitis	2	4.7	7	5.6
Number of compound fractures	42		124	
Total of infected wounds	8	19.0	24	19.3

genographically of osteomyelitis, and consequently are considered merely soft-tissue infections.

4. Infected wounds with osteomyelitis.

In this group are the wounds from which sequestra were extruded or removed, which had a persistent sinus tract leading down to the bone, or which showed by x-ray changes consistent with osteomyelitis. Table II lists these patients. This table is presented to demonstrate the importance of the size and character of the wound in relation to the infection of the bone.

Table III is a tabulation of the wound healing in the two series of cases.

Incidence of Infection

In order to make this report as accurate as possible, we have endeavored to list and compare most of the important factors, other than the use of the drug, which have some effect on the incidence of infection in these wounds. Three of the factors are listed in Table IV. The character of the initial surgical treatment of the wound is more difficult to control accurately. However, all of these cases were treated by a routine method. The surgeons were either of a small group of attending men, or were Residents in Orthopaedic Surgery, working under the supervision of one of the faculty. The time elapsing between injury and arrival in the operating room was in most cases from two to five hours, with no significant variation in the two series. Finally, the amount of tension under which the wound was closed, a factor of recognized importance in production of infection, is not recorded in most of the notes; so we have not attempted to evaluate this factor.

TABLE IV

FACTORS FAVORING WOUND INFECTION IN THE TWO SERIES OF CASES

	No Local or General Sulfonamide		Local Sulfonamide	
	Number	*Per cent.*	*Number*	*Per cent.*
*Large wound	58	46.7	22	52.4
Grossly dirty wound	14	11.3	8	19.0
Bone protruding through skin	11	8.8	9	21.4

* Any wound over one inch in diameter or length

Infection occurred in eight (19 per cent.) of the forty-two cases in our series, treated with the drug; this is almost the same percentage as in the series of Baker. In his report of 252 fresh compound fractures, treated with local sufonamides and primary suture, there were forty-seven infections, or about 18.6 per cent.

Two conflicting reports comparing wound healing with and without the use of sulfonamides have appeared in the literature. Jensen and Nelson report infection in 27 per cent. of the compound-fracture wounds treated without the drug. In their cases in which

the drug was used, only 3.3 per cent. were infected. Not all of their cases were treated by primary closure.

Meleney, on the other hand, after studying a large group of these wounds, concluded, "The combined local and general, or the general, use of sulfonamides alone have not lowered the incidence of local infection".

SUMMARY

1. The records of 166 compound fractures occurring in the long bones have been studied.

2. All of these fractures were treated by primary suture, following débridement and irrigation. Forty-two of the total number had one of the sulfonamides applied locally in the wound, and thirty of these received systemic treatment in addition.

3. Definite infection occurred in 19.3 per cent. of the wounds treated without the drug. Infection developed in 19.0 per cent. of the wounds in which the sulfonamide drug was implanted.

4. We have not attempted to classify the infections as trivial or serious. However, the percentage of serious infection, as evidenced by osteomyelitis, was about the same in the two series.

5. We cannot show that the local use of sulfonamide in these cases altered the incidence of infection.

6. In our two series of cases, early and careful débridement and irrigation were apparently the most important factors in preventing infection.

NOTE: The author wishes to express his appreciation to Dr. Samuel C. Harvey and Dr. John S. Lockwood for their excellent suggestions in the preparation of this paper.

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TUBERCULOSIS OF THE SPINE

A Case Report

BY DAVID M. BOSWORTH, M.D., NEW YORK, N. Y.

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Recovery from tuberculosis of the spine, following extensive fusion, may be so complete as to cause a watchful Pathology Service to upbraid an active Orthopaedic Service for having performed spine fusion on an assumed diagnosis of tuberculosis of the spine, some years before the patient's death. In the following case, recovery had occurred to such an extent that the Pathology Service notified the Orthopaedic Service that on autopsy absolutely no evidence of tuberculosis of the spine could be found five years following fusion. The pathologists questioned the necessity of such a procedure. This query was startling, and the following case report is presented so that the reader may decide for himself.

The patient was a Puerto Rican, thirty-three years old, when referred from another hospital in New York City in May 1938. Thoracentesis of the right chest was done, yielding 100 cubic centimeters of yellow pus. Rib resection on the right was carried out, and a large, paravertebral abscess was found, which upon evacuation proved to be tuberculous. The patient was transferred to Sea View Hospital.

At Sea View Hospital, he was found to have a draining sinus over the previously resected right ribs (seventh and eighth), with a slightly narrow disc space between these segments of the spine, and a

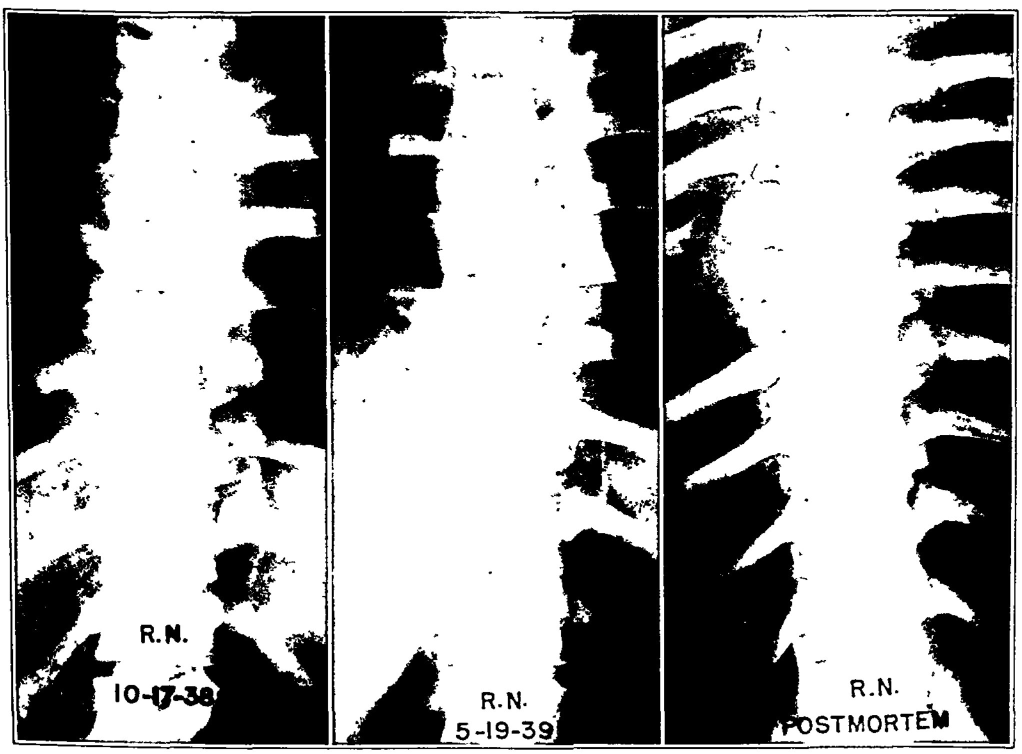

Fig. 1-A | Fig. 1-B | Fig. 1-C

Fig. 1-A: R. N. Paravertebral shadow of third to twelfth thoracic vertebrae with slight narrowing of the disc of the seventh thoracic vertebra.

Fig. 1-B: Shadow of the paravertebral abscess has decreased in the seven months following spine fusion.

Fig. 1-C: X-ray just before autopsy. Five years since Fig. 1-B.

FIG. 2

Gross specimen of spine split showing slight narrowing of the disc of the seventh thoracic vertebra with apparent vacuolation of center. Roentgenogram shows some calcification of the disc of the seventh thoracic vertebra without ... [illegible] ... ment of the

FIG. 3

Photomicrograph showing concentric area composed of hyalinized connective tissue surrounded by loose connective tissue. No other such areas were found. This is a tiny residual for such massive previous involvement.

massive soft-tissue paravertebral shadow, extending from the third to the twelfth thoracic vertebra. A diagnosis was made of tuberculosis of the spine with probable involvement throughout the extent of the abscess. A left hemi-spine fusion was performed in November 1938, and shortly thereafter the right side was fused; the fusion being extended upward to include the sixth cervical vertebra. On gross examination, at the operative procedures, the posterior elements of the spine were found to be free of disease. Solid ankylosis of the spine was secured. The rib sinus healed; the patient's general condition improved; and he became ambulatory, although he remained under observation.

Because of continuous low cervical pain, but without evidence of involvement of the cervical spine, fusion was extended upward in October 1943 to include the third cervical vertebra. Subsequently the patient developed a right hemiplegia which resulted in death in March 1944.

An unusually careful and extensive autopsy showed some fibrosis of the paravertebral tissue throughout the cervical and thoracic regions. Of the many sections made about the seventh and eighth thoracic vertebrae and the intervening disc, only one showed abnormality, consisting of "a concentric area composed of hyalinized connective tissue surrounded by loose connective tissue". Grossly, the disc of the seventh cervical vertebra appeared slightly narrowed, with a somewhat vacuolated appearance. There was no evidence of tuberculosis grossly or microscopically.

The presence of a paravertebral abscess in the thoracic region is the earliest criterion for diagnosis of tuberculosis of the spine, far antedating bony or interspace changes. At Sea View, we accept such criteria as diagnostic, and proceed with fusion to cover the involved area. Therefore, it is important to realize that complete recovery from a pathological as well as a clinical standpoint may occur, as in the present case where there had previously been what the author considers to be absolute proof of tuberculosis.

The patient's death was apparently due to multiple emboli and infarctions which were found to involve the lung and the kidney, and presumably the brain. Bronchopneumonia was a terminal finding. The source of the emboli was atherosclerosis of the aorta with ulceration.

EPIPHYSITIS OF THE ISCHIAL TUBEROSITY

A Case Report *

BY PAUL E. MCMASTER

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Failure of bony fusion of the secondary epiphysis of the ischial tuberosity with fragmentation, resulting in painful disability, is a rare occurrence, and no report of such a condition was found in the literature. Therefore, having encountered such an unusual case, it seemed that a report might be of interest.

The patient, white male, nineteen years old, was a Private First Class in the Marine Corps. He was admitted to the Hospital September 17, 1944, complaining of pain in the left buttock and limb. He gave a history of having first experienced pain when, at the age of fourteen, while running, he jumped down an incline of a few feet and landed on his left foot. Immediately he had such severe pain in the left buttock that he fell. Pain was so extreme that he was unable to get up, and had to be taken home in the car of a passing motorist. The patient spent nearly four months in bed, getting up only occasionally. Toward the end of this period, with assistance, some weight-bearing was possible.

For several weeks thereafter he walked with a limp and required the aid of a cane. Gradually the pain which was "deep in the left buttock" decreased. At this time, the patient saw a doctor, and roentgenograms were made, which showed a "chip off the left hip bone".

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FIG. 1

Anteroposterior roentgenogram of pelvis, showing failure of bony fusion of an enlarged and fragmented secondary epiphysis of the left ischial tuberosity. Irregularity in outline and density of the apposing bony surfaces and the intervening cartilaginous plate is noted.

Approximately a year later, he was able to play baseball and football. However, at various times while engaged in athletics pain in the left buttock and limb occurred, which did not confine him to bed, but kept him out of athletics for a few days. Rest, heat, liniment, and massage gave sufficient relief so that he was able to resume the sport.

In the Spring of 1943 the patient played on the varsity baseball team of a large southern university, and had no significant recurrence of his trouble. He joined the Marine Corps in July 1943, and went through boot camp training as well as "staging operations" with only an occasional flare-up of pain, but he did not report to sick bay. He had been with the initial invading force at Guam, and on his twelfth day of fighting, August 2, 1944, he received a superficial bullet wound of the right arm, and jumped into a foxhole, landing on his buttock. He immediately had severe pain in the left buttock, similar to all the previous attacks. He was unable to move and morphine was required to control the pain. Soon thereafter he was moved by stretcher to a boat, then to a ship, and was evacuated through two mobile hospitals before arrival at this Base Hospital.

Physical examination revealed a well developed white male, nineteen years of age. The superficial bullet wound of the right upper arm was nearly healed and causing no trouble. With difficulty the patient got out of bed and walked, having a marked left limp. He stood with left knee and hip flexed, bearing weight on the right. There was moderate bilateral lumbar muscle spasm with limited spinal motions approximately 75 per cent. of normal in all directions. These motions, especially forced flexion, caused pain in the left buttock and limb. There was tenderness over both the sacro-iliac and lumbosacral areas, as well as of the lower sacrospinalis muscle groups.

Marked tenderness was present on deep palpation over the left ischial tuberosity, which was noticeably larger than the right. No mobility of the epiphysis was demonstrable. At rectal examination, tenderness of the left perineal floor and lower left sacro-iliac region was noted.

The limbs were of equal length, but the left mid-thigh revealed one inch of atrophy and the calf one-half inch, compared to corresponding points of the right. Motion of both hips, particularly of the left, was limited and, when forced, caused pain in the left ischial area. All other joint motions of the lower extremity were normal. Straight-leg raising was limited to 70 degrees on the right and 55 de-

grees on the left. Stretching of left hamstring muscles was very painful. Lasègue's sign was negative bilaterally. Reflexes and sensations revealed no abnormal findings.

Roentgenographic study revealed failure of bony fusion of a large irregular fragmented secondary epiphysis of the left ischial tuberosity. Apposing bony surfaces were irregular in outline and density, and the intervening cartilaginous plate showed some irregular density suggestive of attempt at bony fusion. (See Figure 1.)

Urinalysis, red and white blood-cell counts, and hemoglobin were normal. A smear was negative for malaria, and the Wassermann test was negative.

After eight weeks of bed rest with daily heat, liniment, and diathermy, moderate improvement was noted, but the patient was evacuated to the United States as unfit for strenuous field and combat duty.

DISCUSSION

The secondary epiphysis for the ischial tuberosity appears at the age of puberty, and unites at twenty to twenty-five years of age, according to Cunningham.

Although the patient was nineteen years of age, when union of the epiphysis could not yet be expected to be complete, there was no indication that the epiphysis was fusing with the diaphysis. The opposite ischium was normal in appearance, and revealed fusion of its secondary epiphysis. Thus it is assumed that the fragmented ununited epiphysis of the involved side will persist, possibly giving rise to recurrent pain in the event of either direct or indirect trauma.

The treatment recommended for this patient was rest, heat, and salicylates for the control of acute exacerbations. He was also advised to refrain from too strenuous physical activity. Surgical intervention did not appear indicated as the patient had always previously recovered from his recurrent attacks, and was improving from this one.

There is no uniformity of opinion as to whether an ununited, fragmented, painful secondary epiphysis should be designated "epiphysitis", "osteochondritis", or "osteochondrosis", as suggested by Harbin. "Strain" was suggested by Watson-Jones for the condition.

A careful review of this patient's history indicates that, at the age of fourteen, indirect trauma with an avulsive type of strain of the secondary epiphysis of the left ischial tuberosity had precipitated his trouble. Thereafter repeated indirect traumata, with an occasional direct trauma, kept the condition aggravated. There was no evidence, either in the history or examination, of any endocrine disturbance or other epiphyseal lesions. The patient was unaware of any similar bone lesion in members of his family. There was no history of any serious systemic disease.

It appears then that this patient's condition is primarily of traumatic origin. Clinical and roentgenographic features are similar to the involvement with subsequent failure of bony fusion of the epiphysis of the tibial tubercle, described by Osgood and Schlatter. Although epiphysitis of the ischial tuberosity suggests an inflammatory or disease process, such a factor evidently did not exist in this case, as trauma seemed to be the main etiological factor. However, as the secondary epiphysis and associated cartilaginous plate of the ischial tuberosity were involved, and since definite pathological changes were present by roentgenographic study, the term "epiphysitis" is used to describe this condition, and is considered to be descriptive in view of our present knowledge of the pathogenesis of such lesions.

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A SIMPLIFIED SURGICAL APPROACH TO THE POSTERIOR TIBIA FOR BONE-GRAFTING AND FIBULAR TRANSFERENCE

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The increasing number of osseous reconstructions of the leg present various problems, and it becomes more and more important that the surgeon have at his command a wide variety of approaches. The writer has been using for several years a simple posterolateral approach to the tibia. This approach is useful in bone-grafting from the posterior aspect, in cases of minor residual infection or extensive scarring of the anterior aspect of the leg. It has also been used for fibular transference, an operation gaining in usefulness as a remedy for extensive loss of bone from the tibia. Priority is not claimed for this method, which probably has been used sporadically by many surgeons, but this simple surgical approach is described in the hope that it will be of aid to others.

SURGICAL TECHNIQUE

The operation is carried out with the patient lying prone or in the posterior oblique position. The lower extremity is prepared in the usual manner for bone surgery. The skin incision extends along the lateral border of the gastrocnemius and soleus on the posterolateral aspect of the leg. Its extent varies with the size of the operative field desired. For exposure of the middle three fifths of the tibia and interosseous membrane, the field which is most easily made available, the skin incision extends inferiorly almost to the lateral malleolus (Fig. 1).

The plane of division between the soleus and the flexor hallucis longus is identified as well as the peroneus longus and brevis, which lie anteriorly and form the floor of the field when the leg is opened. Reflection of the soleus and the flexor hallucis longus is then made to the medial side. This bares the posterior face of the fibula, which is the landmark for orientation in this approach. Deep retractors are inserted to pull the posterior muscle mass medially. As this is done, the tibialis posterior is dissected in part from its origin on the posterior aspect of the interosseous membrane. As this latter separation proceeds, the posterior muscle mass falls to the medial posterior side of the leg with greater ease. The only vessels or structures of even minor importance which are encountered in this approach are the muscular branches of the peroneal artery, seen high in the wound in association with the peroneal muscles. It is to be noted that the posterior tibial artery, vein, and nerve are not exposed, and are retracted medially in the muscle mass, since they lie between the tibialis posterior and the flexor hallucis longus.

The dissection at this stage is seen in Figure 2. The posterior half of the fibula is prominent in the lateral border of the wound. The entire fibular shaft, with the exception of the fibular head and the lateral malleolus, can be easily explored by subperiosteal dissection. Practically no bleeding is encountered, inasmuch as the deep dissection is concerned chiefly with the separation of the fibers of origin of the tibialis posterior from the interosseous membrane. The flat posterior surface of the tibia is exposed in its entirety, except for its upper fifth, which is in intimate relation to the popliteus muscle and the first portion of the posterior tibial vessels and nerves. Because of these latter structures, the posterior approach is undesirable for exposure of the tibial condyles. The surgeon should note that the flat posterior aspect of the tibial shaft is an excellent surface from which to cut reversible grafts, and for the application of onlay bone grafts. Room is available for the operation of the motor-driven saw when adequate retraction of the

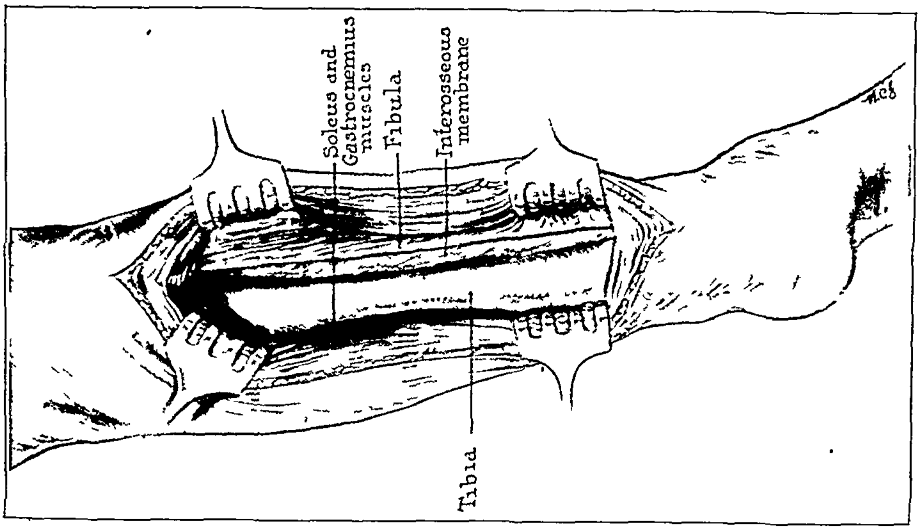

FIG 3

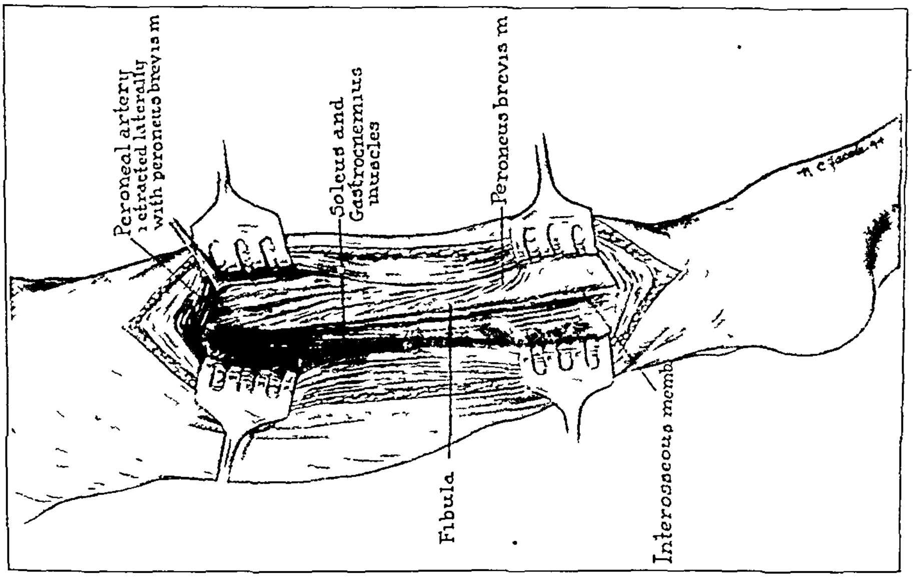

FIG 2

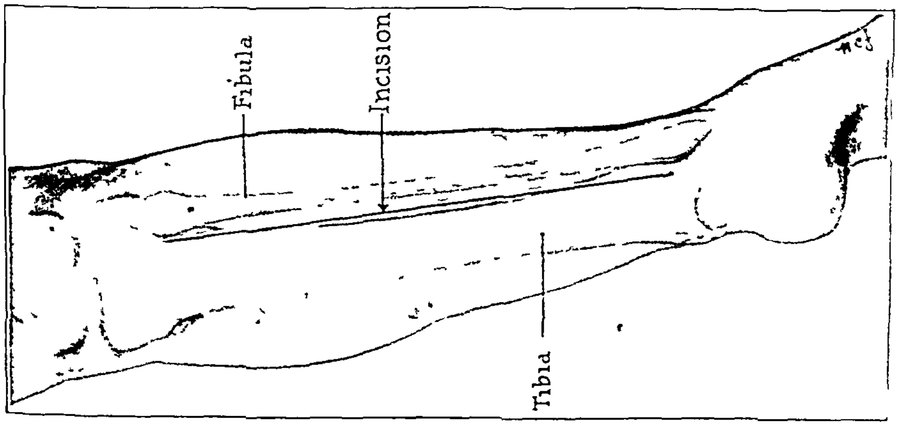

FIG 1

posterior muscle mass has been secured. For the synostosis operation, the appropriate procedures can be carried out with a full view of all structures. The exposure in the depths of the wound is shown in Figure 3.

At the termination of the operation, immediate release of the retractors permits the posterior muscle mass to resume its normal place. In the closure, it is necessary only to unite the deep fascia on the lateral side of the leg with a few interrupted stitches, and subsequently to close the skin. There is no danger of skin necrosis, as the skin of this portion of the leg is pliable, and there are many thicknesses of muscle between the skin and any bone which may have been added. The author has never observed circulatory difficulties or difficulties in healing of the wound, following the use of this approach.

FRACTURE-DISLOCATION OF THE BASE OF THE FIFTH METACARPAL

A Case Report

BY CAPTAIN BAXTER L. CLEMENT

Medical Corps, Army of the United States

Isolated dislocations of the base of the fifth metacarpal are rare, and have been reported infrequently. A review of the literature reveals that McWhorter reported one case in 1918, stating that he had been unable to find any record of a previous case. Roberts and Holland of the Liverpool Royal Infirmary reported four cases in 1936.

CASE REPORT

Sergeant F. R., white male, twenty-four years old, was admitted to the Station Hospital on May 23, 1944, complaining of severe pain and deformity of the right hand. He gave a history of striking the dorsum of the hand, over the fifth metacarpal, on the edge of a table, while scuffling with a fellow soldier.

With the exception of the injured hand, physical examination was negative. There were no marks or bruises on the hand. There was moderate swelling over the base of the fifth metacarpal on the dorsal aspect. The outstanding objective findings were modified claw position of the hand, complete loss of knuckle of the fifth metacarpal, ulnar deviation of the little finger, and inability to approximate the little finger to the ring finger. There was a minimum of local reaction, and the first clinical impression was that the deformity might have been the result of an old injury. A photograph (Fig. 1) of both hands was taken for comparison, which illustrates the deformity. Roentgenogram of both hands, also taken for comparison, revealed a dorsal dislocation of the base of the right fifth metacarpal on the carpal hamate. It also showed a minor fracture of the base of the metacarpal on the radial surface. There was slight shortening of the metacarpal.

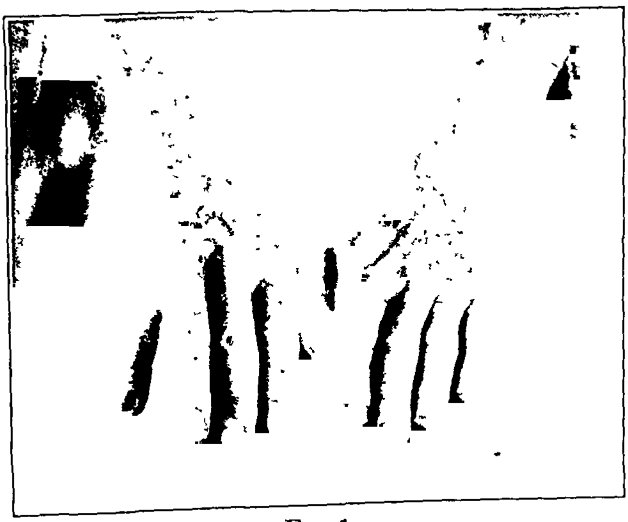

Fig. 1

Photograph of both hands illustrates the deformity of the right hand, and cupped position of hand. There is absence of knuckle to little finger, and ulnar deviation of the finger.

The patient was given sodium pentothal intravenously, and, with traction on the little finger, together with pressure over the base of the fifth metacarpal from the dorsal surface, reduction was comparatively easy, but occurred

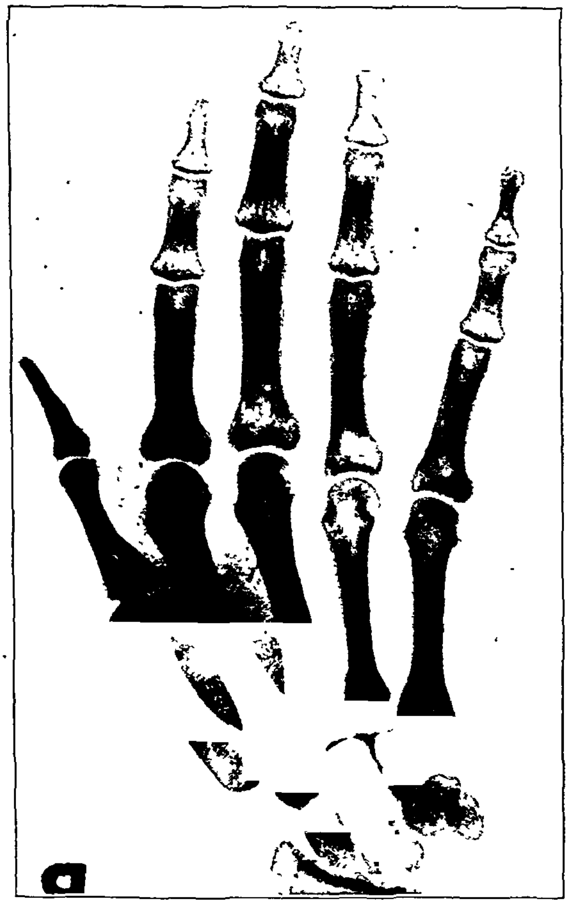

FIG. 2
Roentgenogram reveals fracture-dislocation of the base of the right fifth metacarpal on the carpal hamate.

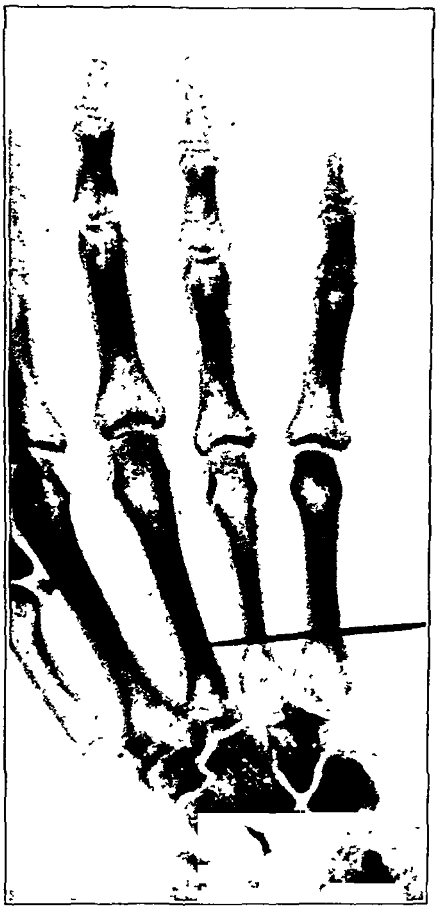

FIG. 3
Postreduction roentgenogram shows reduction and fixation with Kirschner wire.

with a crunching sound which could be heard across the operating room. The reduction could not be maintained, and the dislocation recurred with the slightest manipulation of the finger. (This same finding was noted by Roberts and Holland.) It was felt that the dislocation could not be maintained with plaster-of-Paris; therefore, a Kirschner wire was inserted in the proximal third of the metacarpals to the little, ring, and middle fingers. After this, no amount of manipulation of the fingers or hand caused a recurrence of the dislocation. The visible deformity of the hand had been corrected by reduction. The knuckle had been re-established, the claw position of the hand had disappeared, and the little finger had resumed a normal position.

Figure 3 reveals the complete reduction obtained. The joint space between the base of the fifth metacarpal and the hamate has been re-established, and appears to be normal.

The soldier returned to duty three days after the injury. On removal of the wire, four weeks after insertion, he had normal, painless motion of the fingers and wrist.

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CHRONIC DISLOCATION OF THE BASE OF THE METACARPAL OF THE THUMB

BY G. W. N. EGGERS, M.D., GALVESTON, TEXAS

From the Department of Surgery, Orthopaedic Division, University of Texas School of Medicine, Galveston

Chronic dislocation of the base of the metacarpal of the thumb offers a functional problem of importance. Movement is impaired rather than lost; and, therefore, the partial disability is often endured. Correction demands stability and retention in reduction,

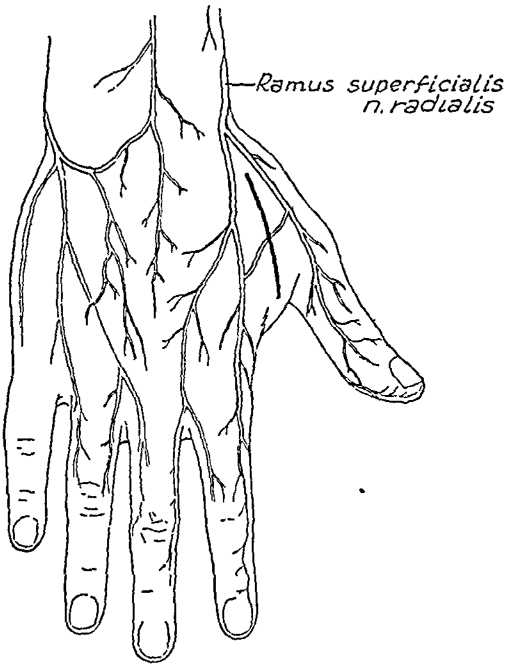

FIG. 1-A
Location of skin incision.

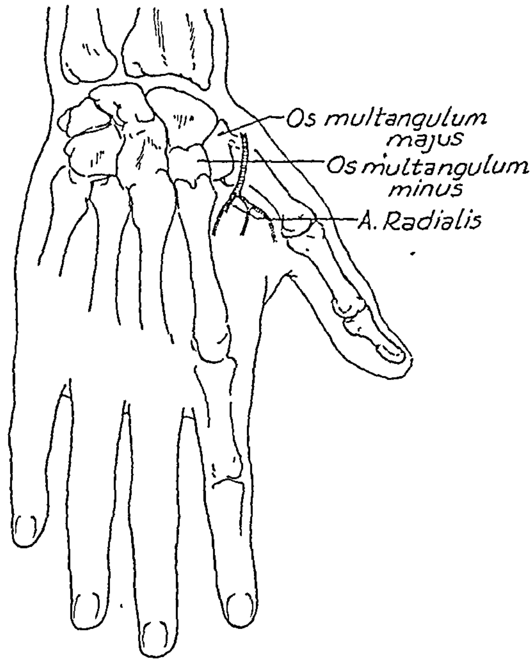

FIG. 1-B
Showing branch of radial artery in the operative field.

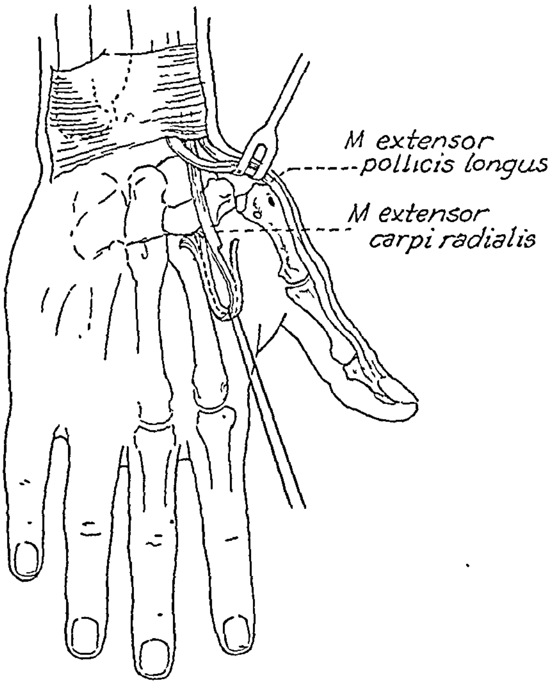

FIG. 1-C
Method of splitting the tendon of the extensor carpi radialis longus.

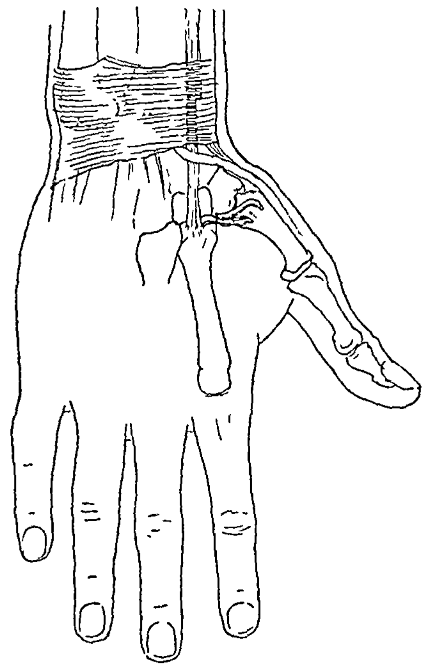

FIG. 1-D
Retention of reduction of the dislocation.

as adduction and opposition are performed. The surgical procedure described has been found to meet functional requirements.

The incision is made on the dorsum of the hand, extending from between the metacarpal of the thumb and that of the index finger to a point proximal to the articulation of the first metacarpal and the greater multangular (Fig. 1-A). It is important to preserve the digital sensory nerves, and these should be seen and retracted. The next step is to identify and ligate the branch of the radial artery perforating the interphalangeal space. This vessel varies in size (Fig. 1-B). The metacarpal is liberated at the base, and the fibrous tissue is removed. (Seldom is it necessary to liberate metacarpal portions of the adductor of the thumb.) The dislocation can then be reduced. The correction of the dislocated metacarpal, which is not easily maintained, is accomplished by utilizing the tendon of the extensor carpi radialis longus. This tendon, inserted into the base of the metacarpal of the index finger, is in two portions,—medial and lateral. The tendon is drawn down from its sheath, and the lateral portion is divided to secure a band (Fig. 1-C). The tendon is released, and the divided band is inserted into the metacarpal of the thumb through holes drilled near the base (Fig. 1-D). It is important that the insertion be near the articular surface for proper retention during adduction and opposition. The tendinous slip is made taut, and is sutured into position with silk. After the usual skin closure, a plaster cast is applied, with the thumb in a position of anatomical rest, and the correction is maintained for three weeks. Return of function is satisfactory.

Fig. 2-A

Fig. 2-B

Fig. 2-A: Chronic dislocation of the base of the metacarpal of the thumb, before correction.

Fig. 2-B: Chronic dislocation of the base of the metacarpal of the thumb, after correction.

CASE REPORT

J. B., forty years of age, was a café proprietor. During the first week of January, 1944, the patient was lifting a "side of beef" which slipped. As it fell, his thumb was caught so as to bear the weight of the beef. There was a severe pain in his right thumb, and he could feel it "slip out of joint". Swelling of the part followed, and he sought the advice of his family physician who reduced the dislocation of the thumb, and applied adhesive to retain the reduction. The diagnosis, made from a roentgenographic study, was complete dislocation of the base of the metacarpal of the right thumb from the greater multangular.

The reduction was not satisfactory, and a splint was applied to the thumb. This method also failed, and a plaster cast was applied. Two weeks later the cast was removed, and the dislocation of the right thumb recurred.

The dislocation could be corrected easily, and the patient would do so at his own pleasure. Retention of the first metacarpal in the normal position was not possible, for redislocation would immediately take place. This condition was quite annoying, because of the instability of the thumb and the pain present when he was working. He was right-handed, which made the condition a handicap to his working efficiency.

On February 4, 1944, the patient was examined, and an open reduction was performed by means of the operative technique described. Anaesthesia was by local infiltration.

Four weeks after operation, the patient had returned to his usual work. The function of the thumb was satisfactory, and was not painful. An examination ten months later revealed that the metacarpal of the thumb had remained in the corrected position and dislocation had at no time recurred.

COMPOUND WOUND OF THE KNEE JOINT WITH RETENTION OF SEA SHELLS AND BEACH SAND

A Case Report

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The physician is occasionally required to treat a single case which presents a multitude of complex problems. Sometimes there is no adequate precedent upon which he can base his decisions. Nevertheless, he regards it as a profitable experience, and feels justified in reporting it and discussing it in some detail. The patient, whose case is herein reported, suffered from a laceration of the quadriceps extensor femoris tendon, a compound wound of the knee joint, the retention of two types of foreign bodies within the knee (one of which was submeniscal in location), and suppurative arthritis. The problems were dealt with in such a way that the patient now has a satisfactorily functioning knee joint.

CASE REPORT

W. B., a white male, sixteen years of age, appeared in the Emergency Room of the New Haven Hospital on August 1, 1943, with the complaint of a cut on his left knee.

About two and one-half hours before admission the patient had run down a sloping beach, and had dived into the water where he struck protruding rocks with his left knee. He was immediately unable either to walk or to swim.

Examination revealed a laceration five centimeters long, located one and one-half to two centimeters above the superior border of the left patella. In the depths of the laceration the cut edges of the quadriceps tendon could be seen, as well as the anterior aspect of the femur. There was total inability to extend the leg.

Roentgenograms showed no evidence of fracture, but in the lateral view there was a small and faint calcific shadow situated behind the femoral condyles. This was absent in the anteroposterior projection.

Therefore, the clinical impressions were laceration of the quadriceps tendon and compound wound of the knee. The patient was taken to the operating room where débridement of the superficial tissue down to the tendon was carried out. The wound was copiously irrigated with saline, and a suspension of sulfathiazole was placed in the joint. No foreign objects were noted. The suprapatellar bursa was sutured by interrupted silk, as were also the tendon and its lateral expansion. The wound was closed without drainage, and a cast was applied with the leg in extension. The patient was given tetanus antitoxin and was placed on sulfadiazine systemically. On the tenth postoperative day, the wound was clean and healed.

Ten and one-half weeks after the injury, the cast was removed, and physiotherapy was started.

About three months after the original injury, a roentgenogram was made because of incidental trauma to the left knee. This revealed that the calcific shadow noted previously was now definitely within the posteromedial compartment of the joint.

An upper respiratory infection developed on December 2, 1943, and nine days later, the left knee suddenly became swollen, painful, tender, and hot. The temperature was 101.6 degrees, and the general physical examination was negative. Aspiration of the left knee yielded seventy-five cubic centimeters of yellow cloudy fluid (not purulent) on which a cell count was 121,000 per cubic millimeter, 92 per cent. of which were polymorphonuclear leukocytes. The smear showed gram-positive cocci in chains, although both the blood culture and fluid culture were sterile. Repeated aspirations, cultured both aerobically and anaerobically, yielded no growth of organisms. The patient's temperature gradually fell to normal on the fifth day.

Following this episode the knee remained swollen and had a boggy consistency to the touch, not unlike that of chronic synovitis. Flexion was possible to 70 degrees (complete extension being 180 degrees).

The patient returned to the Hospital on February 11, 1944, with the statement that, while walking the night before, he had noticed a "soft" but "not bony" resistance to flexion deep within the knee. A few hours thereafter the joint had become painful and swollen. The temperature was 100.8 degrees. Aspiration yielded a cloudy fluid, which was negative to culture, and smears showed no organisms.

Further roentgenograms revealed that the "joint mouse" had been broken up into three pieces. Therefore, the patient was admitted for arthrotomy on February 16, 1944.

OPERATIVE PROCEDURE

The region of the left knee was prepared and draped routinely. A posteromedial approach to the posterior compartment was used. The tibial collateral ligament was divided vertically at the junction between the oblique and straight portions. The synovial membrane of the posterior compartment was incised, and a moderate amount of synovial fluid escaped, which contained what appeared to be beach sand. Irrigation, the introduction of gauze tips, and digital exploration all failed to produce the foreign bodies, and although it became possible for the operator to visualize the entire posteromedial compartment, nothing came into view. Roentgenograms taken at this time, however, showed that the three radiopaque calcific bodies were still present, apparently in the posteromedial compartment. It was then realized that the floor of the compartment was on a level with the superior aspect of the posterior horn of the medial meniscus. Furthermore, it seemed from the roentgenogram that the level of the foreign bodies was more nearly that of the superior surface of the tibial plateau or, in other words, underneath the medial meniscus. Accordingly, the posterior horn was dissected free, and the space between the tibial plateau and the medial meniscus was opened. This, for want of a better term, might be called the submeniscal compartment.

At this point, the two smaller objects became visible, and appeared to be pieces of a sea shell. It was not until the meniscus was lifted up, however, that the third and largest piece of the sea shell was found embedded in the inferior aspect of the meniscus. The largest measured three-sixteenths of an inch (0.5 centimeter) in its greatest diameter, and each of the two smaller measured one-sixteenth of an inch in its greatest diameter. After irrigation the wound was closed with an interrupted silk technique.

Within less than twenty-four hours after the skin closure, the temperature had already reached 103 degrees. The patient became violently ill with a temperature reaching to 103.2 degrees daily, a pulse of 120 to 140, and respirations of 35 to 40. The general physical examination (including that of the lungs) was negative. Culture of the wound was sterile, and the blood culture was negative. The knee was aspirated of purulent material which yielded a hemolytic staphylococcus aureus. This organism fermented mannite and was coagulase positive.

The joint was aspirated and irrigated with saline through the aspiration needle for fifteen minutes, and 5,000 units of penicillin were injected into the joint daily. This was followed twenty-four hours later by another irrigation and more penicillin. Such treatment was continued for five days. At this point the irrigation was discontinued, and 10,000 units of penicillin were injected into the knee joint every other day for two weeks.

On the tenth postoperative day, the leg was placed in skin traction of about five pounds on a Thomas splint with a Pearson drop. The splint was so arranged that the patient himself could give the knee passive motion in traction through 90 degrees of flexion to complete extension. Discharge to the Clinic took place four weeks after admission to the Hospital.

At present the patient has volunteered the information that "the sense of deep heat inside the knee" has gone. There is no effusion. Extension is complete, and flexion is possible to 60 degrees from 180 degrees, and is still improving. There is no relaxation of the knee, either in an anteroposterior or in a lateral direction. The knee is painless. The patient walks without a limp, can go up and down stairs without difficulty, and plays easily at strenuous sports, such as baseball and handball.

DISCUSSION

Only one case of a laceration of the quadriceps tendon[6] has been found in the literature, but there are at least seventy-seven cases of rupture of the quadriceps tendon reported. From these it can be gathered that suture of the tendon and immobilization in a cast for from two to six weeks is the preferred method of treatment. The choice of the length of time the leg is immobilized should be guided by what is known in regard to the rate of tendon healing, the forces it must withstand, and the function expected of it. Mason and Allen have pointed out several features, valuable to the intelligent management of a sutured tendon. According to their findings, it would seem that a lacerated tendon should be immobilized for three weeks, and then function should be started gradually.

However, it should be remembered that the quadriceps muscle has a large heavy tendon, and that the stresses put upon it are probably greater than those upon any other tendon in the body. Consequently, it is probably best to immobilize lacerations of the

quadriceps tendon for from six to eight weeks. The period of ten and one-half weeks in the case reported here is perhaps needlessly long.

A feature of cases of knee injury which has been emphasized constantly is the surprisingly profound and rapid atrophy of the quadriceps muscle. Measures to maintain the muscle in good condition, such as massage, stimulation, and quadriceps-setting exercises, have been advised and followed. However, relatively few authors[1,2,5,21] have pointed out the importance of the extensor apparatus to knee flexion. In the present case, postoperative flexion was limited to 95 degrees. The patient complained of a subjective feeling of resistance anteriorly overlying the region of the musculotendinous junction, upon attempting active flexion. Objectively, passive flexion of the knee was suddenly limited at the time when the quadriceps bellies were felt to become taut, firm, unyielding bands not unlike fibrous tissue to the touch. The limitation was not due to adhesions in the suprapatellar bursa. During the course of physical therapy aimed at stretching the quadriceps, the consistency of the muscle approached normal, and the flexion improved. It is urged that in cases showing limitation of flexion at the knee, this point be kept in mind, and treatment directed specifically to stretching the extensor apparatus.

Foreign bodies within the knee may be derived from two main sources, those introduced from without (exogenous foreign bodies) and the chondro-osseous bodies arising within the joint (which might be termed endogenous).

The common sites for endogenous bodies are the suprapatellar bursa, the anterior compartment, the medial aspect of the lateral femoral condyle, and occasionally the posterolateral compartment.

Mention has been made in the literature of various exogenous bodies,—needles, glass, wood, metal, and bullets. However, the combination of sea shells and sand is unique. The position of the shells was likewise interesting. Geist[12] reported a case of a chondro-osseous body under the lateral meniscus anteriorly. In 1929, the same author reported a second similar case of a loose body in the same obscure location, beneath the anterior horn of the lateral meniscus. In his series of 150 operations upon the knee, this position had occurred twice. Upon cadavera Geist found that there was adequate room under the lateral meniscus to hide a penny or a button. In 1928, Bizarro reported a case in which a fragment of glass was removed from underneath the posterior horn of the lateral meniscus.

It will be noted that the present case represents the first, so far as the writer has been able to determine, in which the foreign object was beneath the *medial* meniscus.

Geist and Bizarro point out, and it was adequately confirmed in this case, that operators usually are not fully conscious of the possibility that foreign bodies can be situated in the submeniscal compartments, either anteriorly or posteriorly. Therefore, it should be emphasized. The small size of the objects in this case did not reduce the difficulties for the operator, and yet, due to their peculiar and strategic position, they caused a severe and recurrent internal derangement. By lifting up the posterior horn of the medial meniscus, they were probably responsible for the patient's complaint that flexion of the knee was resisted by a soft object.

The roentgenograms were reviewed postoperatively in an attempt to see whether a submeniscal position could have been predicted. The only observation which may be of value was that the object was very near the level of the tibial plateau, and that foreign bodies in the posterior compartment, as ordinarily understood, would be expected on a level higher than the tibial plateau by about the thickness of the meniscus.

Platt has recommended what was attempted by the author, namely "compartmental" surgery of the knee. He states that "the joint cavity is divided into five distinct but intercommunicating compartments—three in front and two behind". These are the suprapatellar, the anterolateral, the anteromedial, the posterolateral, and the posteromedial. It would seem that these must now be increased to include the two anterior submeniscal and the two posterior submeniscal compartments. The various compartments of the knee joint

are formed by synovial reflections. Fullerton has made an excellent study of the surgical anatomy of the synovial membrane, and the submeniscal pockets are clearly outlined. Snell has filled the knee joint with a radiopaque material, and by roentgenogram has demonstrated these pockets bulging posterior and inferior to the menisci.

Much of the information on suppurative arthritis has come from war experience with compound wounds of the joint, in which foreign bodies were retained. Postoperative infection of this joint has been studied by Milch and Raisman, and their conclusion was that the incidence of infection varied directly with the complexity and the duration of the operation and with the size of the incision.

In this case, the operator was particularly vigilant not only of his own technique, but also of that of every member of the team. No break in technique came to his attention. Because of the curious submeniscal location of the foreign body, the operation was complex and long. However, neither the beach sand nor the sea shell was sterile when it was introduced into the knee. The patient had had a few febrile episodes of pain and swelling of the knee, which must be looked upon as transient and very mild attacks of suppurative arthritis. The temperature was already 103 degrees, within twenty-two hours of the closure of the skin, instead of after the usual three to five days, when infections from faulty technique are expected. Consequently, it seems more likely that the infection resulted from the removal of contaminated material from the joint with the breaking down of the protective wall of fibrous tissue.

The management of suppurative arthritis of the knee can be difficult. One is confused by the numerous methods in the literature, but all of them have three common features.

The first of these is evacuation of the pus, whether or not the joint is drained surgically. The greater number of surgeons favor drainage. On the other hand, some rely upon aspiration, either single or multiple, to evacuate the pus.

The second principle is an attempt to sterilize the contents of the joint, chemically, mechanically, or by chemotherapy. Chemical sterilization is illustrated by the use of iodoform gauze, flavine, mercuric chloride, ether and "bipp", peroxide and carbolic, phenol and camphor, or ether. In most of these methods, the mechanical effects of dilution and lavage cannot be excluded. Some surgeons have utilized irrigation with saline alone to bring about the desired result of sterilizing the joint fluid. Perhaps in the future such drugs as penicillin, as it was used in this case, will prove to be of the utmost value in cleansing joints.

The third principle in the management of suppurative arthritis, especially in the knee, is the question of motion or immobilization. It has been pointed out that absolute rest of the part is one of the best ways of combatting infection and of ensuring the later mobility of the joint[4,18]. However, some writers have felt that motion in the joint expresses the purulent material from the various pockets, and prevents formation of adhesions and muscle atrophy. The motion may be either active, assisted active, or passive in traction, as in the case reported here.

Tobin, Eggers, and Everidge have described apparatus not unlike that used in this case to give passive motion in traction. The advantages of this method are that the joint surfaces are distracted somewhat, and, therefore, do not become eroded; that the muscle spasm and pain are relieved by traction; that the motion of the joint empties the pockets of pus and prevents the formation of adhesions; and, lastly, that it can be carried out by the patient himself.

It would seem desirable, therefore, to treat suppurative arthritis of the knee by early surgical drainage, by thorough irrigation at operation, leaving the wounds open without drains, and by early passive motion in traction. When surgical drainage seems undesirable, daily irrigations through an aspirating needle plus the intracapsular administration of penicillin are at least feasible, and may in the future prove to be the best method.

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A SPLINT FOR THE CORRECTION OF EXTENSION CONTRACTURES OF THE METACARPOPHALANGEAL JOINTS

BY LIEUTENANT COLONEL I. WILLIAM NACHLAS
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Extension contracture of the metacarpophalangeal joints is a common sequel to injuries of the hands and arms. It is usually the result of prolonged splinting by plaster casts, prepared splints, contracture of the skin and tendons, or disuse resulting from nerve and blood-vessel damage in the upper extremity. After the contracture has developed, attempts to move the joints produce pain, so that the patient tends to continue the splinting subconsciously. A vicious circle is thus begun. There is, of course, a similar deformity resulting from intrinsic damage to the joints, but this constitutes a separate problem.

The proximal finger joints in extension are particularly prone to fixation, with contracture of the capsules, the capsular ligaments, and the periarticular structures. Bunnell points out that infiltration of serofibrinous material between the various layers surrounding the articulations causes interference with the gliding of the tissues. Furthermore, the collateral ligaments are normally so attached to the bones that, although they are relaxed when the joint is extended, they become taut when the joints are flexed. If these ligaments become fibrosed or shortened, they act as checkreins to prevent flexion.

The inability to flex these joints constitutes a serious disability, because the hand cannot be closed. When there is an associated stiffening of the interphalangeal joints, the entire hand is "frozen" or "congealed". The use of the hand as a prehensile instrument is lost. There is also marked impairment in the holding qualities of the hand, when the proximal finger joints alone are maintained in fixed extension.

Because of the importance of restoring to the hand its grasping function, a number of procedures have been used to correct this deformity. Physical therapy has been resorted to, but has proved to be of only limited value when used by itself. Manipulation of the joints under an anaesthetic is said to cause a tearing of the periarticular tissues, with resulting protective reaction that frequently leads to further splinting and fibrosis. Because of this, manipulative surgery has been decried by many authorities. Occupational therapy, properly used, has been helpful, but the course of treatment is long, and its efficacy is dependent on the cooperation of the patient. Surgical intervention offers prompter correction, and has consisted chiefly of excision of the capsule on either side of the affected joint.

In the belief that continuous mild traction can restore the flexibility of the tissues fairly promptly with less damage to the joint structures, there has been developed a traction device in which tension is supplied by rubber bands. The problems of controlling the degree of tension, the direction of the pull, the ease of adjustment, and the comfort of the patient all presented themselves, and it has been possible to meet these requirements without making the splint too complicated in construction or too difficult to control. The splint consists of two basic parts,—first, a foundation splint which serves to keep the wrist in a cock-up position, to supply a fixed point for the attachment of the traction bands, and to afford a simple adjustment for the direction of the pull; and second, the traction unit which includes the elastic bands that supply tension.

The foundation consists of a cock-up splint of the type that was at one time used for immobilizing Colles's fractures. It is placed on the volar side of the forearm and palm, and strapped to the arm by a broad webbing. A longer, narrower strap fixes the palm part of this splint, so that it does not slip forward in the hand to interfere with flexion of the metacarpophalangeal joints. A U-shaped wire bar is held attached to the cock-up splint

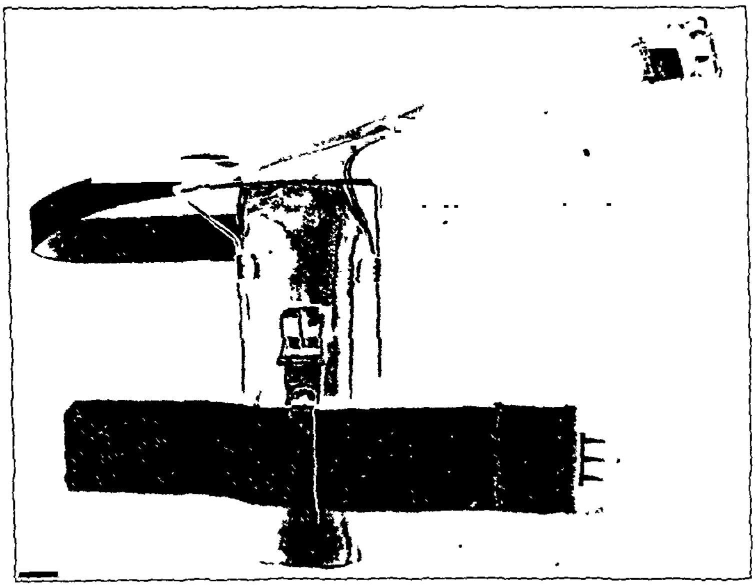

FIG. 1
Foundation splint with fixation straps.

by loops that permit the bar to be moved longitudinally. By regulating the position of this bar, one can control the direction of the traction. A buckle on the anterior surface of the splint supplies a point of fixation for the tension strap (Fig. 1).

The traction apparatus consists chiefly of a broad leather strap on the back of the hand, fixed at its proximal end by a webbing strap around the wrist (Fig. 2,*D*). At its terminal portion, this leather strap is cut longitudinally to digitate it. The end of each of these "digits" is sewn back on itself around a rubber band. The rubber bands for each of the "digits" are collected at their distal part, and held in a small wire catch that is sewed into a narrow leather strap which, in turn, is to fit into the buckle on the forearm. Specifications for the splint as it has been used in this hospital are as follows:—

SPECIFICATIONS OF SPLINT

Foundation Splint (Figs. 1, 2,*A*, 3,*A*, 3,*B*, and 3,*C*).

The material used is 18-gauge aluminum, three and one-half inches wide at the proximal portion, and three inches wide near the wrist. The forearm part is curved to fit the convexity of the volar surface of the forearm. At the wrist, the splint is bent up to hold the palm in the cock-up position. The distal end of the splint, which fits proximal to the metacarpal heads, is curved forward, so as to avoid cutting into the palm of the hand. On the concave side, there is glued a layer of light-weight sheepskin. In the palm of the hand, a metatarsal arch pad, three-eighths of an inch thick, is placed under the leather lining to permit maintenance of the transverse arch of the hand as recommended by Bunnell (*a* in Fig. 3,*B* and Fig. 3,*C*). On the convex surface, a monel-metal band is riveted longitudinally to serve as a strap retainer (*b*). The distal rivet also fixes a one-inch leather loop that holds a five-eighths-inch buckle (*c*). On the convex surface, near the long edges, there are riveted four monel-metal loops to grasp the sliding bar snugly without preventing its being pulled longitudinally (*d*). The sliding bar (*e*) is made of one-eighth-inch wire, and forms a U with the two arms of the U inserted through the monel loops. Near the wrist, the sliding bar is bent forward to form an angle of 120 degrees. Two webbing straps are used to fix the splint to the hand, the first (*D*) a two-inch webbing, twelve inches long, with a two-inch buckle to be slipped through the monel strap retainer (*b*), and to be buckled on the back of the forearm; the other (*E*) a one-inch webbing belt, twenty inches long, and with a one-inch buckle used to fix the distal end of the splint. If there is any tendency for the strap to slip off, two punch holes, one-quarter of an inch in diameter, may be made in it to fit over the corners at the end of the splint. The strap may be further secured by the sheepskin lining over it, as in Figure 1.

Traction Unit (Figs. 2,*D* and 3,*F*).

A piece of calfskin is cut to conform to the back of the hand and the proximal phalanges (*g*). The distal portion is cut longitudinally to permit four digitations, the ends of which are sewed back on themselves (*h*) around medium-heavy rubber bands (*k*). The

length of this leather should be such that, when it is fixed by a webbing strap and buckled (*f*) around the wrist, its digital ends (*h*) will reach just beyond the knuckles (first interphalangeal joints). The four rubber bands are then fastened by means of a wire rectangular loop (*m*), one and one-quarter by three-quarters of an inch, made of one-eighth-inch wire, to a leather strap (*n*), five-eighths of an inch wide and five inches long, with perforations at intervals of one-half of an inch for the buckle on the foundation splint. The thumb, because of its special mechanics, does not usually require traction.

APPLICATION OF THE SPLINT AND MODE OF ITS USE

The foundation cock-up splint is placed on the volar aspect of the arm and palm, with the terminal portion kept proximal to the crease in the hand (Figs. 4, 5-A, 5-B, 6-A, and 6-B). The broad webbing belt fixes the forearm part. The long narrow strapping is then applied in such a way that it will prevent the displacement of the brace distally. This is quite important. If the brace is pulled toward the fingers, it blocks flexion of the metacarpophalangeal joints. The strapping is stretched across the terminal portion of the brace, and then is looped around the back of the wrist in a figure-of-eight which crosses on the back of the hand. The buckle should be placed in such a position that it will not be under the leather piece of the traction unit (Figs. 5-A and 5-B). The traction unit is then applied in the following manner: The leather piece is placed on the dorsum of the hand, and fixed in position by means of a webbing around the wrist. The fingers are then passed through the rubber bands with the leather digitations reaching just distal to the proximal interphalangeal joints (Figs. 6-A and 6-B). The sliding bar is adjusted to a position which will permit the direction of the pull to be where desired. The

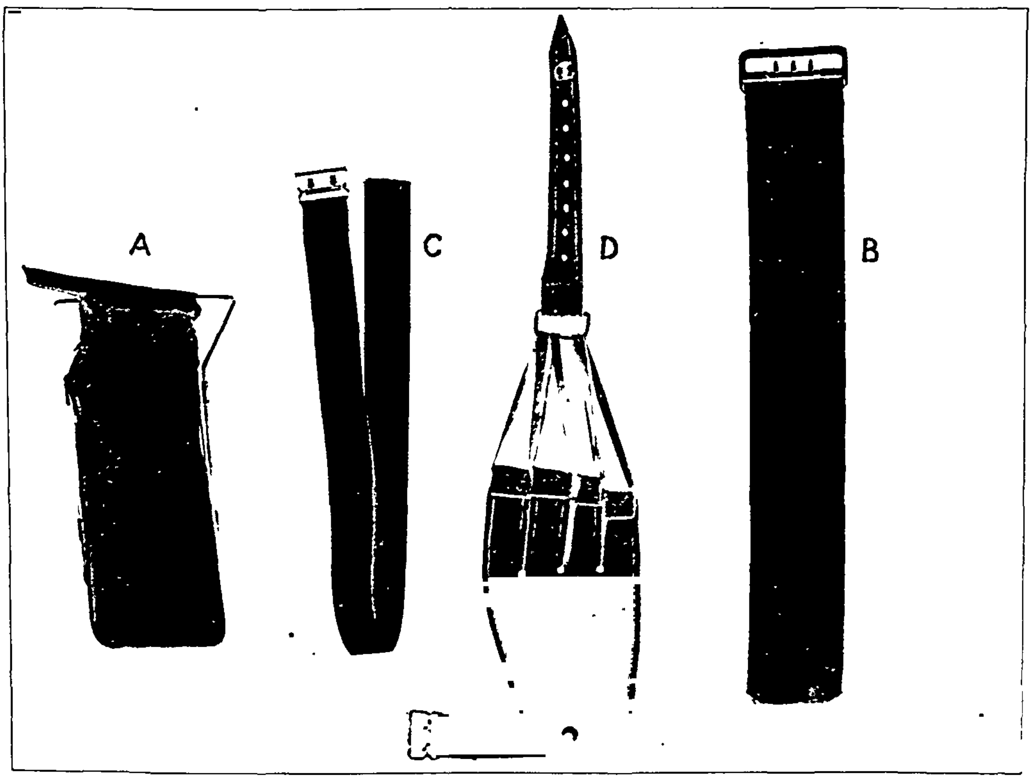

FIG. 2

Individual parts of the splint. *A:* Concave aspect of foundation splint. *B:* Forearm strap. *C:* Strap for fixation of palmar portion of splint. *D:* Traction unit.

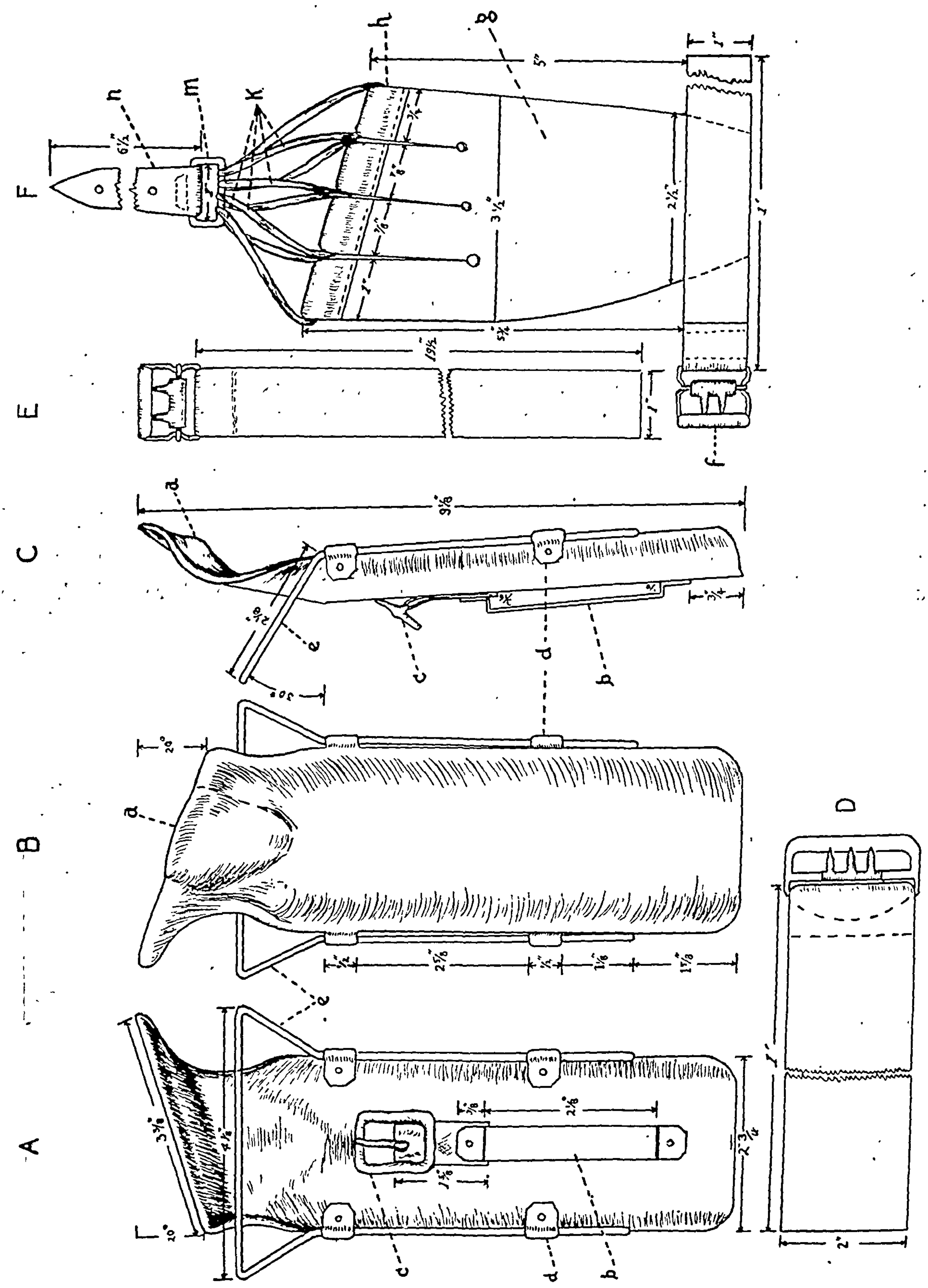

FIG. 3
Drawings of the component parts of the splint with measurements of a standard model.

strap on the other end of the rubber bands is then pulled over this bar, and is fixed to the buckle on the volar surface of the brace at the desired tension.

It is desirable that the brace be inspected daily so that the direction of the pull may be changed, and the amount of traction altered to meet the changing position of the fingers. It will be noted that the terminal parts of the fingers are given freedom of action, and the patient should be encouraged to use his fingers in full extension and flexion, when the brace is being worn. The use of these joints is of considerable value in restoring gliding function and necessary length to the tendons. It is desired that the splint be worn throughout the day, but it may be removed for short periods of time to permit the patient to wash his hands and to actively exercise his hand and fingers.

The splint is intended for the treatment of extension contractures of the metacarpophalangeal joints. When used for this purpose, it may be expected to help restore flexion in a relatively short period of time,—from several days to several weeks. After a fair arc

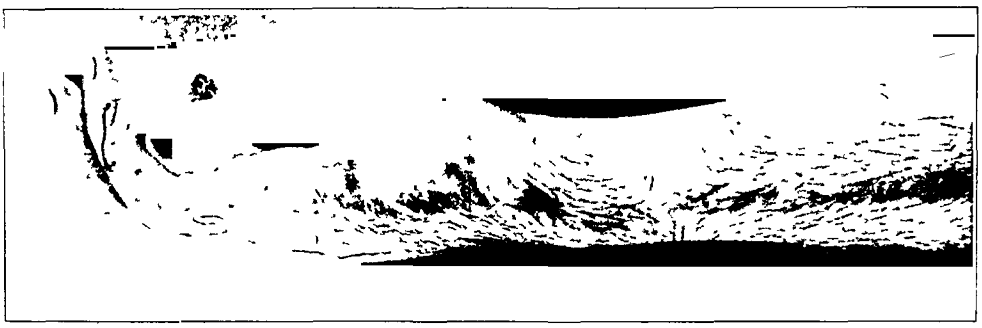

Fig 4'
Photograph of a hand with extension contractures of the metacarpophalangeal joints

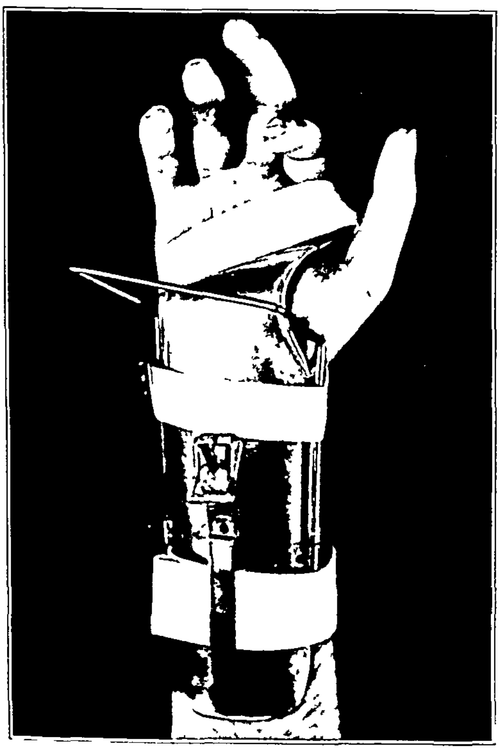

Fig 5-A

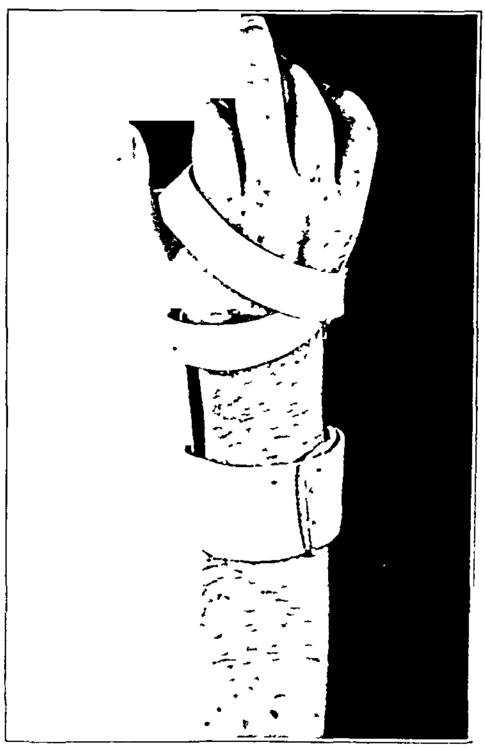

Fig 5-B

Photographs of a "frozen" hand wearing the foundation splint

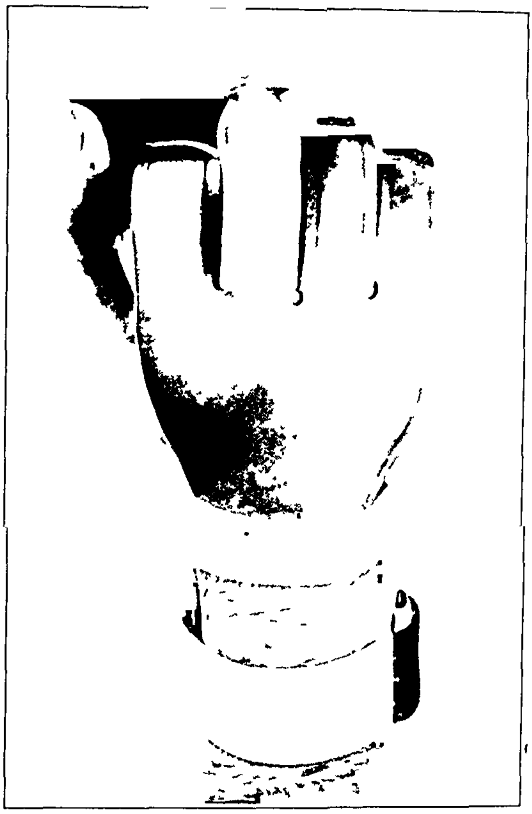

Fig. 6-A

Fig. 6-B

Splint assembled on hand. Volar and dorsal views.

of motion has been acquired (usually two-thirds of the normal range), it is desirable that for at least part of the day the splint be removed, so that occupational therapy may be used. In addition, physical therapy is usually helpful at this stage of the patient's progress.

The successful use of the splint in fifty consecutive cases warrants its recommendation for the specific purpose for which it has been designed.

CORRECTION OF POLIOMYELITIC DEFORMITIES WITH FROTHED LATEX PROSTHESES

BY ADOLPH M. BROWN, M.A., M.D., CHICAGO, ILLINOIS

From The Illinois Eye and Ear Infirmary, The University of Illinois, Chicago

In the past two decades, spurred no doubt by the casualties of two wars, facial prostheses have come to have an established and recognized place in plastic surgery. As the public becomes accustomed to what is being done in the way of prostheses for the face, requests have come for restorations hitherto considered not only beyond the scope of plastic surgery, but also beyond the scope of prosthetics. One's first impulse is to tell such a patient that the restoration asked for is not being done. But the plastic surgeon who does prosthetic work must realize that his office or clinic is the court of last resort for such patients and, if he has no restoration to offer, the patient may become convinced that his case is hopeless. We are besieged by requests not only to restore missing parts of the face, but also to restore the breasts, the hand, the buttocks, the penis, and the calf of the leg.

Small prostheses for the face can be made of solid rubber or hollow rubber, molded by relatively simple techniques. Prostheses for the breast, the buttocks, and the calf of the leg, if made by the same technique, would be heavy, bulky, unwieldy, and relatively non-resilient. They should be light enough in weight so that a relatively small amount of adhesive will keep them in place, or so that no adhesive at all is necessary. They should also, unlike facial prostheses, have the rebound elasticity characteristic of the organ which they replace. For instance, when the artificial ear is bent forward and released, it should spring back into place immediately, as does an ordinary ear. Likewise, the artificial calf of the leg when pressed with the finger, should rebound at the rate normal for calf tissues.

In this paper is presented the technique of making a prosthesis which restores the contour of the lower limb, correcting the deformity caused by atrophy of the limb. The deformity is usually caused by poliomyelitis, and is the result of atrophy of the muscles themselves. Other defects, such as shortening of the limb, may be present in the affected extremity. These are corrected by operation to eliminate the limp, before the patient presents himself for a prosthesis. Atrophy of the foot is generally untreated, except for stuffing the normal size shoe with cotton or orthopaedic pads to make the inside of the shoe small enough to fit the foot. Even after the gait is normal, the slender "broomstick" appearance of the affected limb attracts unfavorable attention. It is to correct the thinness of the limb that such a patient desires a prosthesis.

The technique is as follows: The limbs are coated lightly with petrolatum jelly (the hair need not be shaved off). A two-piece negative impression is made in soft plaster-of-Paris (Fig. 2), a mold being made of both the affected limb and the normal limb. The negative impressions are removed, then are reassembled, plugged at one end, and filled with alpha gypsum (Fig. 4). The negative portions are then removed and discarded. The patient is placed upright with his shoes on and the malleoli are identified by suitable marks upon the positive cast. The positive casts of both the deformed limb and the normal limb are mounted vertically on a small plaster pedestal, so that the malleoli of the normal and of the deformed limbs are at the same distance from the work table (Fig. 5). The positive plaster cast of the normal limb is used as a model for the reconstruction of its mate. This eliminates numerous visits by the patient to pose for the sculpture of the prosthesis. With the normal cast as a model, sculptors' clay is applied over the cast of the deformed limb and is molded to the shape required, in bold sweeping contours to match the normal limb. This is checked with a caliper, so that the diameters at all levels of the two casts are almost

equal. The sculpture is so performed that the restored limb is made a little larger in all diameters to allow for the very slight shrinkage of the prosthesis during vulcanization. Once the sculpture has been completed, the clay is smoothed down with wet cotton wipes, and is permitted to dry smooth. It is then painted with a fine varnish. The varnish is applied so that, when the flask is made later, the plaster adjacent to the sculpture will not dry at a faster or slower rate than the other plaster in the mixture. Evenness of crystallization tends to make for a stronger cast.

The ensemble (Fig. 6), consisting of the model of the deformed limb bearing its sculptured and varnished restoration, is now a core around which is built a two-piece mold. This is done by imbedding the ensemble longitudinally halfway into a fresh mixture of alpha gypsum plaster, contained in a long cardboard box. After this has hardened, a petrolatum, a soap solution, or a commercial separating compound is applied to the surface of the plaster still exposed, and the remainder of the cast is made by pouring another batch of alpha gypsum mixture over the ensemble, as illustrated (Fig. 7). This is permitted to dry for several days, since it is necessary to permit the entire cast to dry evenly and thoroughly in exact position for at least several days in order to prevent warping.

When thoroughly dried, the cast is carefully pried open. The model of the deformed leg is removed, and the clay is washed out thoroughly. The three portions of the cast may then be dried and reassembled (Fig. 8). If some of the shellac, varnish, or lacquer remains clinging to the inside of the plaster mold, it may be removed by rubbing with acetone, ether, or alcohol. This gives the inside of the plaster mold the same porosity throughout. The reassembled mold now consists of two halves of a rather thick hard plaster shell, bearing longitudinally between them a core which is a replica of the *deformed* limb.

Unlike the casting procedures for the smaller facial prostheses, it is not necessary to construct a flue or pouring channel for prostheses of the limb. The prosthesis is made of frothed rubber; if it is to be made of commercially frothed or sponged rubber, it is necessary to reproduce the entire cast in aluminum. This may be done in an aluminum foundry; however, this procedure is time-consuming, tedious, and expensive. We now use a rubber compound which, unlike commercially frothed or sponged rubber, does not require vulcanization under extreme heat and pressure. Therefore, the prosthesis may be processed in the original hard plaster cast. The dry mold

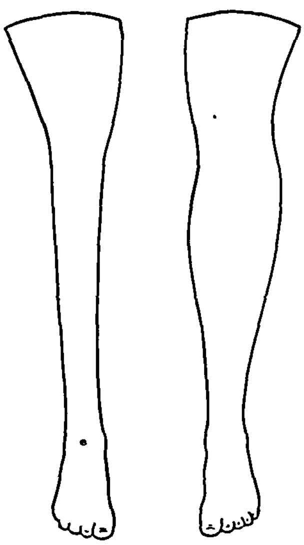

FIG. 1
Comparison between lower limbs with and without poliomyelitic deformity.

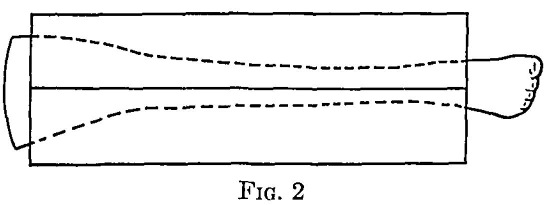

FIG. 2
Two-piece negative mold.

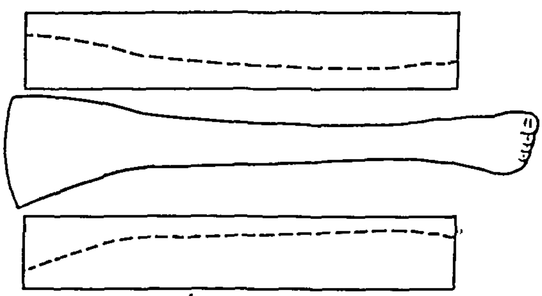

FIG. 3
Two-piece negative impression disassembled.

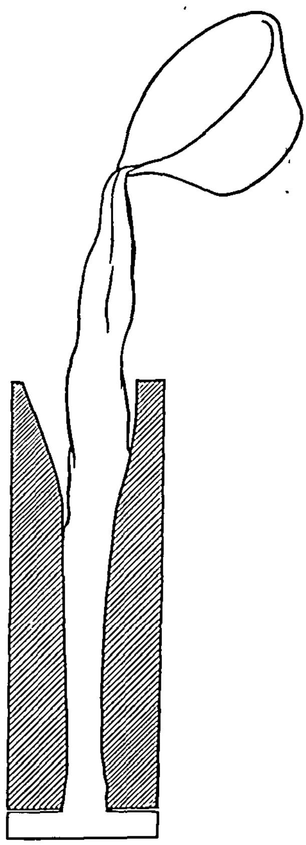

FIG. 4
The bottom is blocked, and the negative impression is filled with hard plaster-of-Paris.

is laid open preparatory for casting. The materials which are used for making frothed latex prostheses are generally bought in the form of a latex compound or a latex compounding dispersion. However, for those who intend to make prostheses, a typical formula for a frothing stock follows:

	Parts by volume
Rubber (as latex, 60 per cent. solids)	100
Sulphur	2
Zinc oxide	2
Zinc mercapto benzothiazole	1
Zinc diethyldithio carbamate	1
Potassium oleate	2
Sodium fluosilicate	1

All of the above ingredients must be dispersed or dissolved in water, so as to be compatible with the latex. There are many other accelerators and soaps, known to the rubber industry, which could be substituted for those shown above, depending upon the properties of the latex and upon processing conditions. However, the compound made up as described requires the minimum of laboratory equipment and offers fewer disappointments.

As we use the compound now, the potassium oleate or soap, the zinc compounds, and the sodium fluosilicate are kept in separate containers. They are combined only

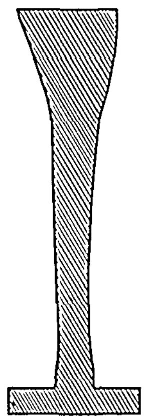

Fig. 5-A

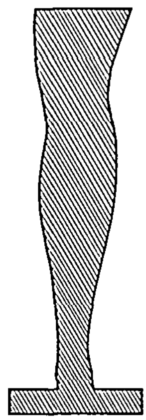

Fig. 5-B

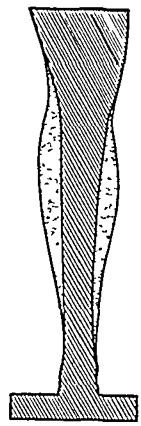

Fig. 6

Fig. 5-A and Fig. 5-B: The negative casts are discarded, and the positive cast of the deformed limb (Fig. 5-A) is mounted on its plaster base.

Fig. 6. The mirror image of the normal limb is sculptured in clay upon the model of the deformed limb. This is varnished.

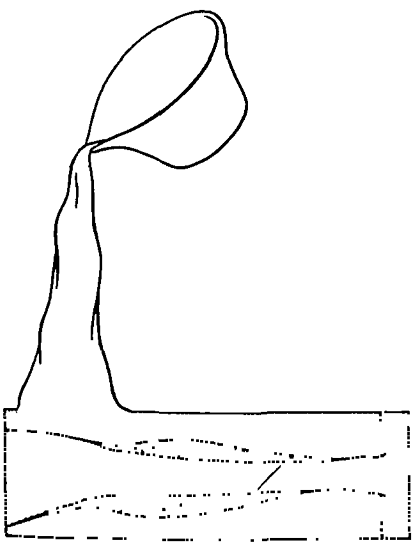

Fig. 7

The model of the deformed limb, sculptured up to normal dimensions, is invested in a two-piece alpha gypsum mold.

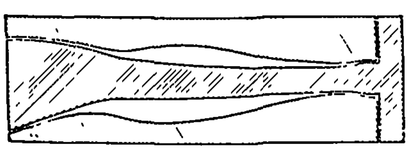

Fig. 8

The clay has been washed out. The mold, reassembled, now consists of two external dies and a core.

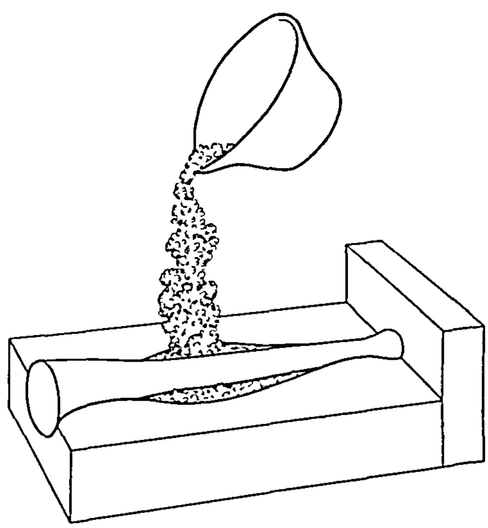

Fig. 9

The two halves of the mold are filled with frothed latex compound, the core is replaced, and the mold is assembled. It is now ready for vulcanization.

when the frothing process is ready to be begun and when the mold is ready to be cast. Others of the ingredients may also be held out of the compound, so as to prevent premature vulcanization. The rubber compound, one-fifth of the volume necessary to fill the mold, is placed in an electric beating machine or rapid mixer, and the compound for frothing (potassium oleate) is added. As the beating continues, suitable colors are added to the agitated mixture. The following colors, each in a 3 per cent. ammoniated solution (since they disperse

FIG. 10
Typical poliomyelitic deformity. Note asymmetry.

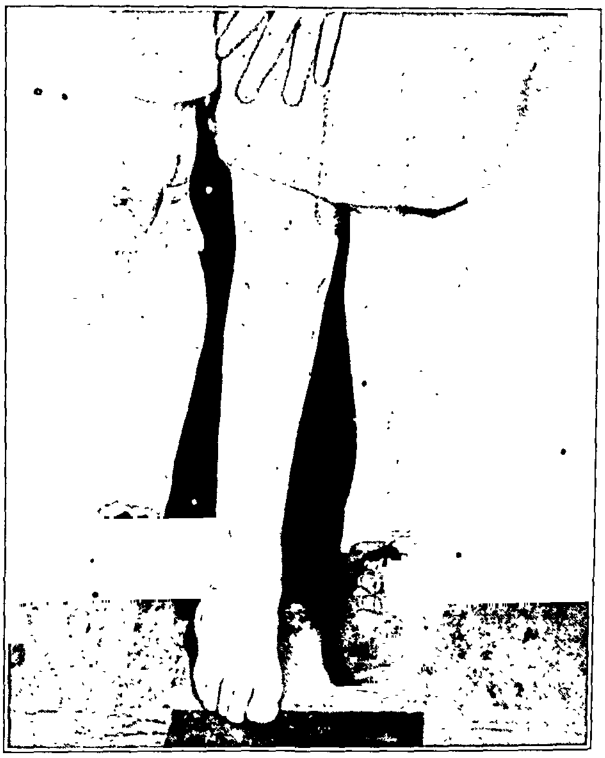

FIG. 11
Showing the latex prosthesis.

FIG. 12
Prosthesis being slipped on like a stocking.

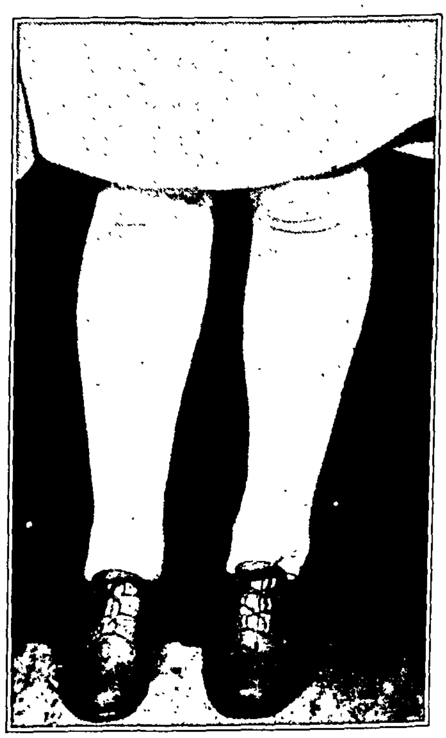

FIG. 13
Prosthesis in place. Note the symmetry of the limbs.

better, when ammoniated), are used, generally one or two drops of red and brown for each ounce of rubber:

DC Red No. 7,
Sudan orange, RRA,
Amido naphthol brown,
Fast scarlet, BA.

Beating the mixture for five or ten minutes is usually sufficient to froth it until its volume is increased about five or six times. When this has been accomplished, the zinc compounds are included, and the mixing is continued for another one or two minutes to disperse the zinc. The sodium fluosilicate is added, and the beating continues for another minute to disperse it well. The frothed mixture, which is extremely light and airy, is then immediately poured into the mold with the core assembled (Fig. 9), and enough excess mixture is added so that, when the entire mold has been assembled, the excess of the frothed rubber will extrude from the mold. The assembled parts containing the rubber are permitted to stand undisturbed for a few hours and are then wired firmly together with stove wire or baling wire. The vulcanization is accomplished by immersing the cast in boiling water for approximately an hour and a half. (If an autoclave is available, the ensemble will be cured after approximately fifteen minutes in steam at 250 degrees Fahrenheit, at fifteen pounds gauge pressure. Vulcanization is possible in an oven, too, but the time will be longer because of poor heat transfer.) Next the cast is cooled, either in the air or under running water. The parts are disassembled, but the prosthesis remains encircled about its core. The rubber part is now rinsed well under tepid running water, the excess water is squeezed out by manual pressure, and the prosthesis is permitted to dry from one to two days at room temperature to finish the curing process. The rubber prosthesis is then removed from its core (it may be washed and dried), the flashing is cut away, and the marks of the cast edges are removed with fine manicure scissors or obliterated by gentle application of a small revolving dental granite stone. There is generally enough shrinkage so that, when the prosthesis is put on like a stocking, it remains firmly in position.

This type of prosthesis is extremely light in weight and is very comfortable to wear, possessing as it does a rebound elasticity, unlike that of prostheses for the face. Pressed or indented with the thumb or fingers, the surface rebounds in almost exactly the same way as does skin. When stockings are worn, the deformed limb cannot be detected by casual inspection.

The colors used for these prostheses are different from those employed in other prostheses. Since this air-frothed rubber is heat-vulcanized, the coloring materials must be not only alkali-fast, and sun-fast, but also heat-resistant.

One has only to see the gratitude shown by patients who are given prostheses of this type to restore deformities of the lower limb to realize that such prostheses have a real place in the field of plastic surgical prosthetics.

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A MODIFICATION OF THE DENIS BROWNE SPLINT

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AND

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The correction of congenital talipes equinovarus is admittedly a problem. The use of the Denis Browne splint has been the simplest solution in most cases. No matter what method or combination of methods is used to obtain a corrected position, however, the process of correction is only partially complete, for there still remains the problem of maintaining the feet in the desired position of overcorrection for a considerable period, often years.

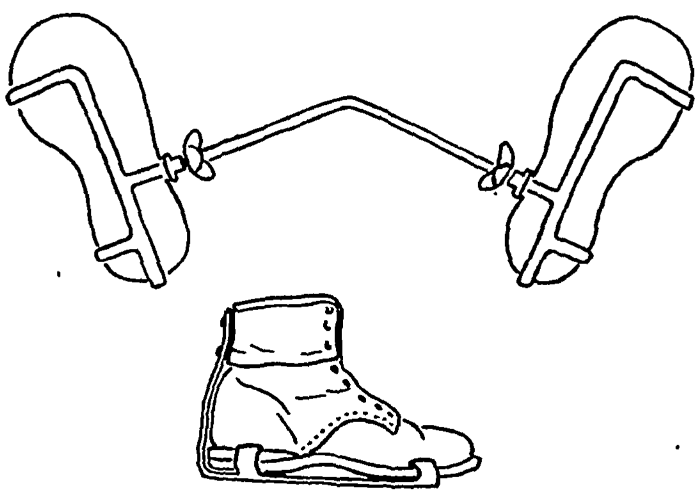

Fig. 1
Details of splint attached to shoes.

The writers wish to describe their modification of the Denis Browne splint, the use of which has several advantages, both to the patient and to his attendants. It consists of a transverse steel rod about five-eighths of an inch (1.6 *centimeters) in diameter*, and is a length suitable for the size of the patient. To each end of this rod is welded a clamping mechanism which grips the soles of the shoes in the manner illustrated, much like roller or ice skates. In addition, posterior T straps are incorporated into the sole clamps. These straps are laced around the patient's ankles with regular shoe laces. In many cases these T straps may not be necessary, but they tend to prevent recurrence of equinus deformity.

This splint has the following advantages:

1. It can be applied to shoes so that the corrective effect the patient receives from his shoes during periods of weight-bearing is continued by the splint during non-weight-bearing periods.

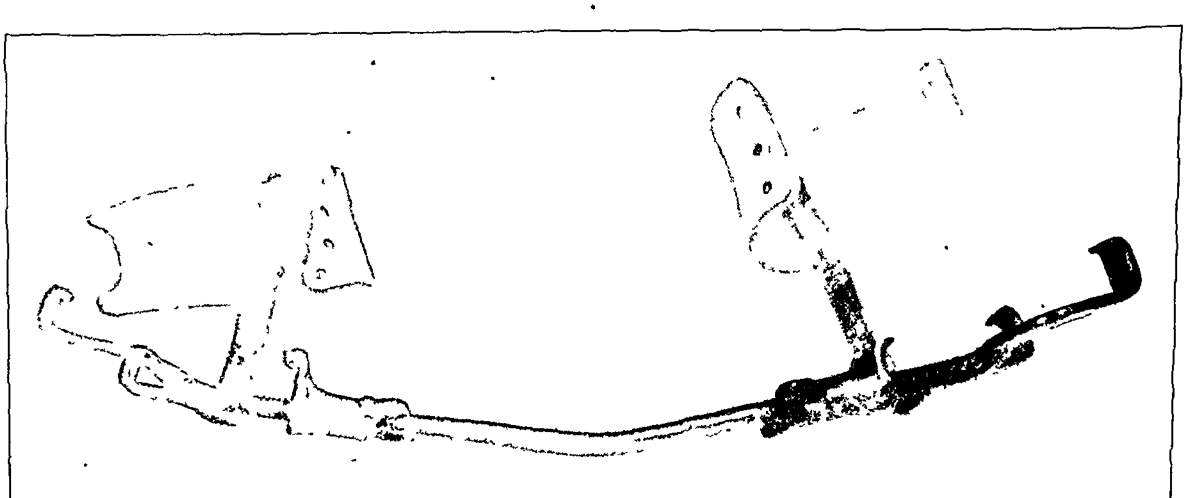

Fig. 2
The splint unclamped from shoes.

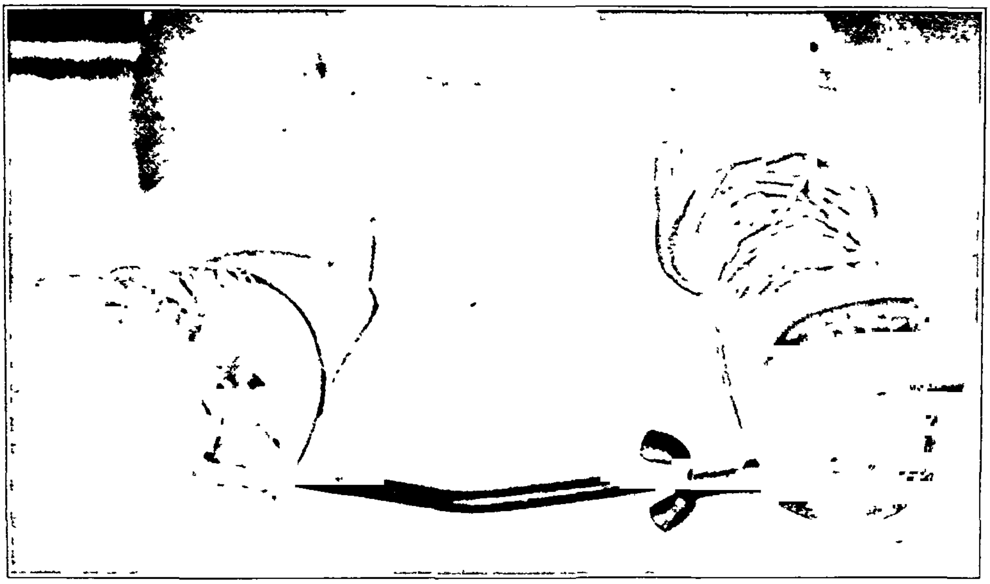

FIG. 3
A patient with the shoes and splint applied.

2. There are no projections on the under surface of the splint, so that the patient can stand up in his crib without puncturing or ripping his bed clothing.

3. Only one pair of shoes is required at a time: an important economic feature, since the shoes can be used for ordinary walking or standing when detached from the splint.

4. The splint is easily made. and can be applied and removed in only a few seconds, so that its use does not involve any great trouble to the patient's parents or attendants.

The usual way in which the writers employ their modification of the Denis Browne splint is to use it continuously with the patient's shoes reversed, until the infant begins to stand and walk. Then the shoes are worn on the correct feet, and a lift is incorporated into the lateral sides of the heels and soles of the shoes so that, when the patient is bearing weight, his ankles are thrown into slight valgus position. Then, during morning and afternoon naps as well as at night, the splint is applied and continues the corrective effect.

A THIRD ROUTINE X-RAY EXPOSURE OF THE ANKLE JOINT

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It has long been the practice to take the anteroposterior and lateral views in roentgenograms of the ankle. These projections may not always show clearly all bone lesions in the fibula. To obtain an oblique view of the lower part of the fibula, a special exposure is necessary. In Figures 1-A and 1-B the lateral malleolus is on the side of the film; the heel is raised four centimeters, and the picture is made, with the central ray directed from behind at an angle of 30 degrees.

This oblique projection shows fractures of the fibula (Fig. 2-C) which might not be clearly visible in the usual lateral view, because the shadow of the fibula is obscured by the shadow of the tibia. While the technique described is not original, its routine use would ensure more accurate diagnoses.

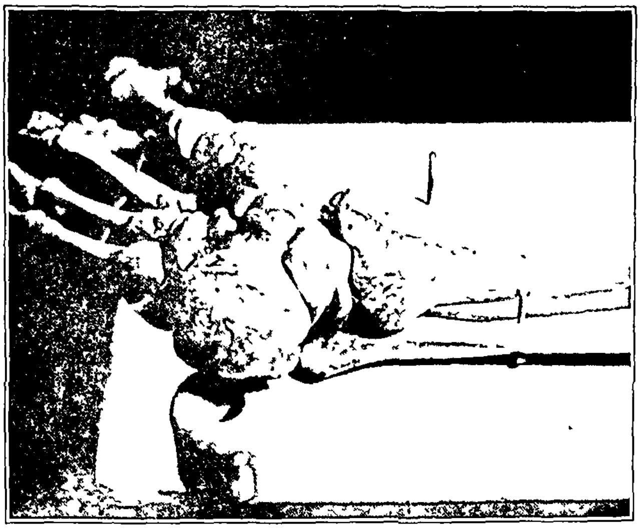

FIG. 1-A
Position of foot for x-ray, with door-stop under os calcis.

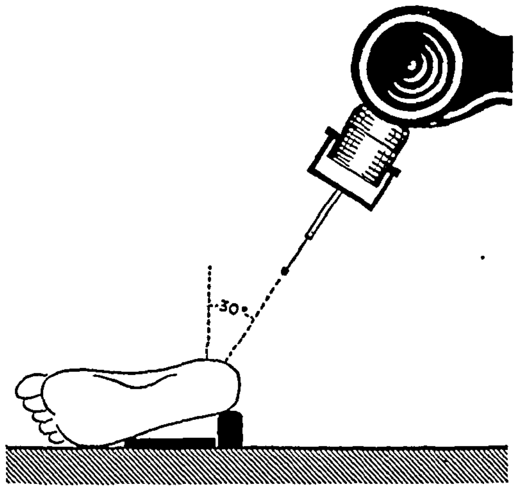

FIG. 1-B
Position of third routine exposure.

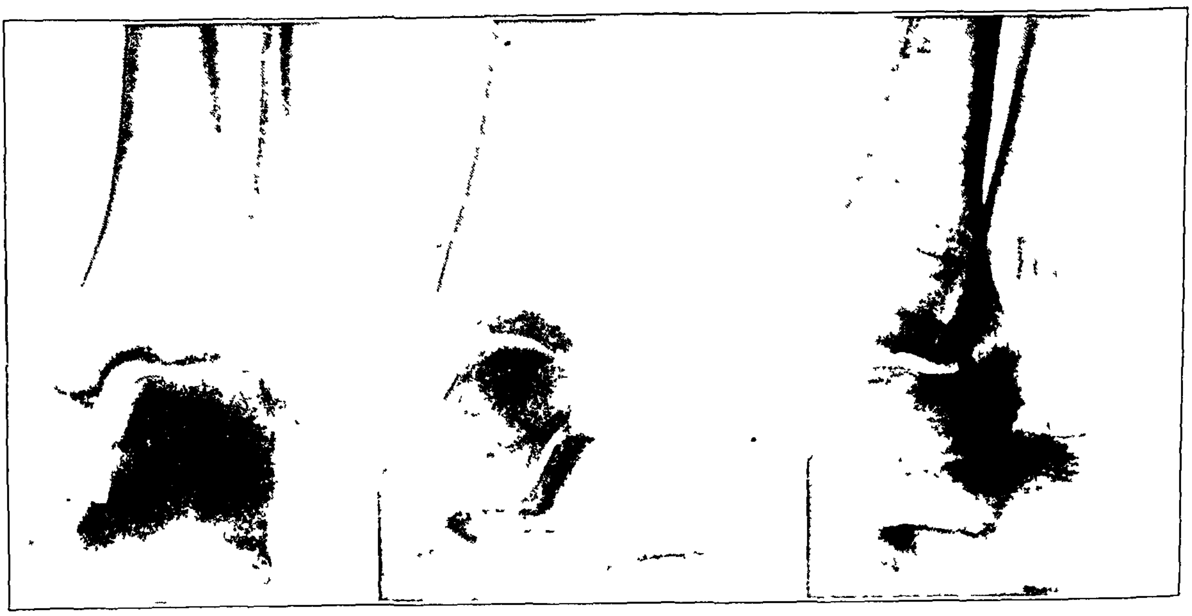

FIG. 2-A FIG. 2-B FIG. 2-C
Three exposures of ankle joint. The special exposure (Fig. 2-C) shows the real extent of fracture.

AN EASY AND ECONOMICAL METHOD OF MAKING REMOVABLE CASTS

BY M. LAURENS ROWE, M.D., CINCINNATI, OHIO

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Rigid splints and supports of various types, which can easily be removed, are frequently desirable in the management of orthopaedic problems. Bivalved plaster casts can be used for intermittent immobilization of the extremities, but they often pinch and bind or slip out of position, and they are inadequate for neck or trunk splinting in the ambulatory patient.

A method, used by the staff of the 297th General Hospital for the application of lumbar body jackets, which involves the incorporation of strips of used x-ray film into ordinary plaster casts, has proved to be economical and efficient.[1] This simple technique of making circular plaster casts for the body has been applied to casts for the neck or the extremities, at the Cincinnati General Hospital, and these have been found to be sufficiently flexible to permit removal and reapplication without cracking.

The cast is applied snugly over stockinette without sheet wadding, and is carefully molded over bony prominences. Strips of used x-ray film are laid between the layers of plaster in a generally circumferential direction at varying angles to give roughly uniform distribution throughout the cast. Strips, two inches wide and twelve inches long, are most convenient for the larger body casts, and strips, six inches by one inch, are used in the cervical spine collars and in casts for the extremities. In the usual lumbar body jacket, for instance, five to seven rolls of six-inch plaster and twelve to fourteen strips of x-ray film are used, making a cast about a quarter of an inch thick. Comparable amounts of plaster and x-ray film are employed in the other casts.

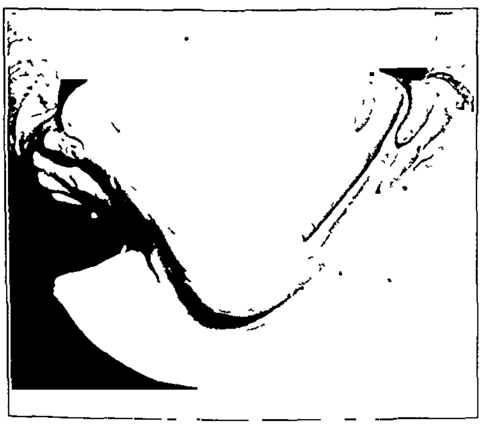

FIG. 1
Cervical spine collar opened from behind, to demonstrate circumferential flexibility.

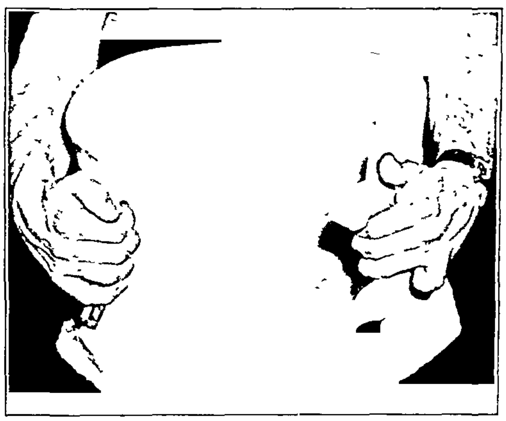

FIG. 2
Lumbar body jacket opened to illustrate flexibility.

A narrow strip of felt is placed under the stockinette along the line on which the cast is to be cut for removal. After the plaster has set, the cast and stockinette are cut along the felt strip and are removed by spreading. The cast is then bound back into its original shape with gauze bandage to prevent warping, and is dried for twenty-four hours. The cut edges are taped, and the cast is fitted with straps and buckles. The completed cast is

[1] A Removable Plaster of Paris Back Support. (News and Comment) Bull. U. S. Army Med. Dept., LXXIX, 11, 1944.

rigid in its long axis, but sufficiently flexible in a circumferential plane to permit easy removal and reapplication without cracking the plaster.

It is felt that this type of cast embodies all the advantages of the celluloid jacket and offers, in addition, simplicity of application and extreme economy. It may often be used in place of formal braces and appliances where, for one reason or another, these are unobtainable.

A SIMPLE GUIDE PIN FOR THE INSERTION OF DEVICES OF INTERNAL FIXATION INTO THE FEMORAL NECK

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To determine the proper length and angle of insertion of the nail or other fixation device used in fractures of the neck of the femur, a simple modification of the Steinmann pin, as shown in Figure 1, may be employed. Beginning at the pointed end of an ordinary Steinmann pin, slots have been filed at half-inch intervals for a distance of five inches. Each slot extends halfway through the thickness of the pin, so that a clear roentgenographic image may be obtained. At a distance of five inches from the point is a one-inch oblique offset, the angle formed between the offset and the long axis of the pin being 125 degrees, an approximation of the normal angle between the femoral neck and shaft.

The fact that the offset makes an angle of 125 degrees with the long axis of the pin is a helpful check feature since, when properly inserted, the offset lies parallel to the shaft of the femur. The slots indicate the correct length of the fixation device to be employed.

The pin is inserted through a drill hole in the cortex, and the angle of the femoral neck is determined by gentle palpation of the medullary cavity, after the method of Watson-Jones.

The marker pin may be inserted at the base of the greater trochanter, and the nail or other fixation device is then driven parallel to and just below it in optimal position. Or the nail may be driven into place in actual contact with the guide pin, superiorly or inferiorly, anteriorly or posteriorly, according to the indications of the check roentgenograms.

Turning the offset away from the side on which the nail is to be inserted provides

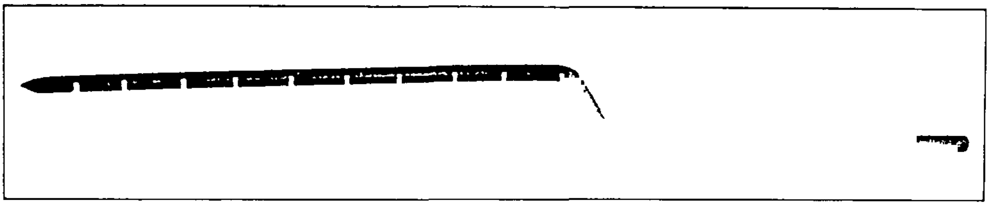

Fig 1
Photograph of the guide pin.

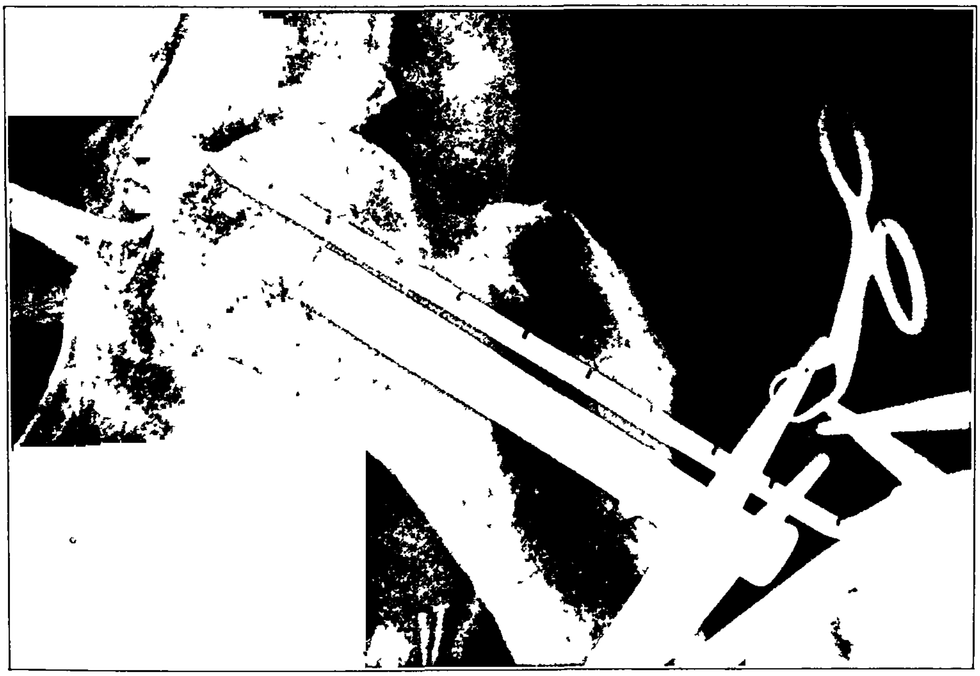

Fig 2
The guide pin has been inserted relatively high in the femoral neck. A Smith-Petersen nail has been introduced below and parallel to the guide pin in optimal position, and has been driven partially into place. The offset is turned away from the nail to provide adequate space for the nail and its driver.

ample space for the driver and, since the measured slots are on the same side of the pin as the offset, affords a smooth surface of pin along which the nail may be driven.

After the nail, blade, or other fixation device has been driven, the marker pin is easily withdrawn with a hand chuck, and final impaction may be carried out and check roentgenograms taken.

The pin combines the advantages of an adequate direction finder, an accurate internal measuring instrument, and a direct and solid guide for the driving of most devices of internal fixation, designed to be inserted into the femoral neck.

W. A. COCHRANE, F.R.C.S. EDIN.
1893–1944

William Alexander Cochrane died at the age of fifty-one in Edinburgh, on November 30, 1944. He is survived by his wife, and a young son and a daughter.

A native of Edinburgh, he received his education at Daniel Stewart's College and at Edinburgh University where he received the degrees of Bachelor of Medicine and Bachelor of Surgery in 1915. Thereafter, as a battalion medical officer, he saw service in France and Flanders, where he was wounded. The wound, a compound fracture of the leg, required active treatment for nearly two years, and this circumstance was largely responsible for turning his thoughts toward orthopaedic surgery. During the latter part of his treatment he was in Bangour Hospital, a temporary military hospital located near his native city, and here later he acted as house surgeon. The Orthopaedic Staff of the Hospital consisted of British and American surgeons, under the immediate direction of Sir Harold Stiles and the more distant control of Sir Robert Jones in his capacity of Inspector of Military Orthopaedics. His association with these two great leaders made an indelible impression upon Cochrane, and from that time he determined to devote his life to the study, the practice, and the furtherance of orthopaedic surgery in Scotland.

After a period of study at Continental clinics, he went to the United States of America, where he acted as a temporary assistant in orthopaedic surgery at the Massachusetts General Hospital in Boston. Cochrane used to refer to Boston as his second spiritual home, and certainly he owed an immeasurable debt to the inspiring teaching of Dr. Joel E. Goldthwait and Dr. Robert B. Osgood, especially in the sphere of medical orthopaedics.

He returned to Scotland in 1921, and took the Fellowship of the Royal College of Surgeons of Edinburgh. At the Royal Infirmary he acted first as Clinical Tutor in the Clinic of Professor Sir Harold Stiles, and later as Assistant Surgeon in the Clinic of Professor Sir David P. D. Wilkie. While his primary interests remained in orthopaedic surgery, during the tenure of these offices, he had an excellent opportunity of obtaining a wide experience in general surgery, which he always maintained was an essential part of the training of an orthopaedic surgeon.

Later he became Associate Assistant Surgeon in Orthopaedics at the Royal Infirmary, and Lecturer on that subject in Edinburgh University. The Edinburgh Orthopaedic Clinic and the Edinburgh Foot Clinic owed much to his service and practical help. In 1934 he played a very active part in the founding of the Princess Margaret Rose Hospital for Crippled Children, of which he was the Surgeon-in-Charge. This Hospital was the first Orthopaedic Hospital built in Scotland. Its extension was curtailed by the outbreak of hostilities, but, by that time, Cochrane had the satisfaction of seeing the Hospital well established, with a network of major and minor clinics covering the southeastern region of Scotland. During the War, Cochrane acted as surgeon to the Emergency Medical Service, and was a Consultant Orthopaedist to the southeast area of the Scottish Command.

In addition to his hospital appointments, Cochrane acted on many committees, and his advice was frequently sought and willingly given on all matters relating to cripples. He was a member of the committee responsible for the Delevingne "Interdepartmental Report on the Rehabilitation of Persons Injured by Accidents", a member of the National Advisory Council for Scotland on Physical Training and Recreation, a member of the Council of the British Orthopaedic Association and of the Scottish Orthopaedic Council. For twelve years he was Assistant Honorary Secretary to the Edinburgh Branch of the British Medical Association, and, at the Annual Meeting of the Association in Winnipeg in 1930, acted as vice-president of the Section of Orthopaedics. He was the author of a textbook on "Orthopaedic Surgery" in 1926, and, jointly with Philip D. Wilson, of "Fractures and Dislocations" in 1925. His contributions to the literature on a wide variety of subjects were distinguished by their clarity, simplicity, and authority.

Big, breezy, and downright, Cochrane had many interests outside his profession. A scratch golfer, he was well known and popular on the golf courses of Edinburgh and East Lothian. His enthusiasm for the game and his skill did not diminish with the years. His tall, striding figure and jovial laugh will be missed at the Association golf meetings.

Cochrane was outstanding in the broad view he took of his specialty. He deprecated the tendency of regarding the orthopaedist principally as an operating surgeon. He was enthusiastic in his advocacy of medical orthopaedics, and, as an exponent of sound body mechanics, he maintained that the orthopaedist's field included the supervision of general physical education from infancy. One of his frequent remarks was that one could not derive full satisfaction from any reconstructive operation, however successful, unless one could be sure that every opportunity had been first provided for the patient to avoid the operation by adequate primary treatment. To his mind the ultimate aim of the orthopaedist was preventive medicine.

A pioneer in the Scottish orthopaedic field, Cochrane's loss will be widely felt, especially in these days of change in medical politics and services, but by his skill, ready sympathy, enthusiasm, single-mindedness, and hard work he has done much to advance his specialty, and has built a foundation on which much that he worked for will surely rise.

SAMUEL CLIFTON BALDWIN
1855–1944

Dr. Samuel Clifton Baldwin, of Salt Lake City, died on October 19, 1944, at the age of eighty-nine. One of the pioneers of orthopaedic surgery in the Far West, he was the first to specialize in orthopaedic surgery in Utah, and one of the best loved physicians in his State.

At the age of sixteen, upon the death of his father, Dr. Baldwin was faced with the problem of supporting his family. Although he was forced to leave school for a time, by dint of hard work and sacrifice, he entered the Louisville Medical College in his home State of Kentucky in 1881. He was graduated in 1884, and after ten years of practice, he went to Salt Lake City.

His work throughout the State was of a highly constructive nature. For many years he was Chief of the Primary Children's Hospital in Salt Lake City. He held membership in the Salt Lake County and Utah State Medical Societies. He was active on the staffs of the Dr. W. H. Groves Latter-Day Saints Hospital, Holy Cross Hospital, and the Salt Lake County General Hospital. Recently he received the honorary degree of Doctor of Science from the University of Utah, of whose Board of Regents he was a member, in honor of his work as a physician in Utah.

In 1903, Dr. Baldwin became a member of The American Orthopaedic Association, and he held memberships as well in The American Academy of Orthopaedic Surgeons and the American Medical Association. During World War I, he served as Lieutenant Colonel in the Army orthopaedic department, and although he sought active service in 1942, he was barred because of his age.

Dr. Baldwin is survived by a son, Albert B. Baldwin, and a sister, Mrs. Lillie B. Reynolds of Louisville.

CARL THORBURN HARRIS
1891–1945

Carl Thorburn Harris, one of the leading orthopaedic surgeons and teachers in central New York, died at his home in Honeoye Falls on April 17, 1945.

Born in Rochester, Dr. Harris received the Bachelor of Science degree from the University of Rochester in 1912, and then went on to the Harvard Medical School, where he was graduated with the degree of Doctor of Medicine in 1916. After a two-year period as surgical intern at the Boston City Hospital, he served overseas with Base Hospital Number 7, as an orthopaedic surgeon. He was a First Lieutenant in the Medical Corps.

At the close of the War, Dr. Harris returned to his native city, and became a teaching fellow in surgical pathology at his alma mater. He later was an Instructor, Assistant Professor, and Professor of Orthopaedic Surgery at the University of Rochester School of Medicine. He was active in medical circles in Rochester, serving as Chief of the Orthopaedic Service, Genesee Hospital; Consultant in Orthopaedic Surgery, Iola Sanatorium and Monroe County Hospital; and Attending Orthopaedic Surgeon, Highland Hospital. He was an Associate Visiting Surgeon at the Rochester General Hospital.

Dr. Harris was a Diplomate of The American Board of Orthopaedic Surgery, and a member of The American Orthopaedic Association, The American Academy of Orthopaedic Surgeons, and the American Medical Association.

Current Literature

Essentials of Body Mechanics in Health and Disease. Joel E. Goldthwait, M.D., F.A.C.S., LL.D.; Lloyd T. Brown, M.D., F.A.C.S.; Loring T. Swaim, M.D.; John G. Kuhns, M.D., F.A.C.S. With a Chapter on the Heart and Circulation as Related to Body Mechanics by William J. Kerr, M.D., F.A.C.P. Ed. 4. Philadelphia, J. B. Lippincott Company, 1945. $5.00.

The appearance of a new edition of Body Mechanics is particularly timely, in view of the present concern with physical fitness. This is the standard book on a basic subject of significance to all branches of medicine. The new edition was prepared in order to make the subject clearer, and to present it more concisely. Body mechanics plays an important rôle in the prevention and cure of a great variety of diseases and disorders. It also is important in the palliation of the diseases of older persons. For this reason a chapter on geriatrics has been added.

The relation between form and function ought not, at this late date, to require either demonstration or defense. But it is unfortunately apparent that, in its application to hygiene and to the care of the sick, this principle does not receive its appropriate share of clinical attention. It is to be hoped that the appearance of this new edition will serve to promote a greater realization of the importance of body mechanics, and a wider application of the principles so forcibly presented.

In furtherance of the development of the young, in the maintenance of health in the adult, and in the prevention and palliation of the degenerative diseases of the elderly, body mechanics assumes vast proportions.

Because of these considerations, it is desirable that this well written and clearly illustrated book should reach a wide circle of students of all ages. Internists will find particularly revealing the sections dealing with the sympathetic nervous system, the circulatory system, and the joints. The relation between posture and physiological disturbances is clearly shown and the appropriate postural treatment is concisely outlined.

Doctors at War. Edited by Morris Fishbein, M.D. New York, E. P. Dutton & Company, Inc., 1945. $5.00.

In "Doctors at War", there have been collected the medical accomplishments of Service doctors on every far-flung battle front. The sixteen foremost authorities responsible for the organization of our Wartime Medicine have written their own exciting accounts of what each branch of the Service has accomplished. In General Hawley's account, we learn how doctors in the European Theatre of Operations prepared for D-Day. Admiral McIntire writes of the duties of the Navy medical personnel, while at sea and under action.

Sharing the responsibility in a less exciting but nonetheless invaluable way, have been the doctors on the home front. Their services to the civilian in his home, and to the laborer in the factory, are given well-deserved praise. There are also interesting accounts of the medical side of Selective Service, preventive medicine as carried out by the Army, the United States Public Health Service, the Veterans Administration, and the Red Cross.

One of the paradoxes of war is that out of all the suffering, bloodshed, and death come medical discoveries which do much to advance the future welfare of mankind. During World War I, influenza was almost as deadly an enemy as enemy gunfire. Since then our doctors have isolated the responsible virus, and the disease is kept under control by drugs and vaccines. At present in the Army, the Bureau of Preventive Medicine includes some of the greatest experts in medicine, and they are dealing with respiratory diseases, air-borne infections, epidemics of all kinds, virus diseases, and tropical diseases. With war as the impetus, the medical knowledge and experience gained by our doctors has been tremendous. The records of lives of wounded men saved in the Army, Navy, and Marine Corps in World War II, as compared to World War I, is a hopeful indication of what medical and scientific progress can achieve in the peace which will follow.

Morris' Human Anatomy. A Complete Systematic Treatise. Edited by J. Parsons Schaeffer, A.M., M.D., Ph.D., Sc.D. Ed. 10. Philadelphia, The Blakiston Company, 1943. $12.00.

There have been some changes in the list of contributors to the tenth edition of Morris' Human Anatomy. Some of the new contributors are: J. C. B. Grant, who has written the section on The Musculature; Bradley M. Patten, whose section covers The Cardiovascular System; Harold Cummins, writing on The Skin and Mammary Glands; and Olof Larsell, and C. M. Jackson, editor of former editions of this book, describing The Digestive System. Other sections include Developmental Anatomy, by

Richard E. Scammon; Osteology, and The Articulations, by Robert J. Terry; The Lymphatic System, by Eliot R. Clark; Special Sense-Organs, by Leslie Brainerd Arey; The Respiratory System, by J. Parsons Schaeffer, editor of this volume; Urogenital System, by Franklin P. Johnson; and The Glands of Internal Secretion, by J. F. Gudernatsch.

Each of the several sections has been revised and brought into line with accepted thought, and some have been extensively rewritten. There is an orderly presentation of each subject, and throughout reference is made in convenient places to the clinical aspects and relations of the systems being discussed. Many new illustrations have been added. The section on Developmental Anatomy appears in entirely new form, with extensive use of laboratory illustrations.

The plan followed in the editing of the book should be of particular value to the student. A bibliographic reference list is given at the end of each section. A complete index of the volume is included.

Rentgenodiagnostica povrejdeniy kostey i sustavov (The Roentgenographic Diagnosis of Bone and Joint Injuries). G. A. Zedgenidze. Moscow, Medgiz, 1943.

The book contains 315 pages, of which ninety-four pages, at the end of the book, represent a small atlas of illustrations. The introductory part considers the general problems of x-ray examination in traumatic injuries of bones and joints, normal and injured bone in the process of regeneration, peculiarities of fractures in children and in old people, general technique, and especially x-ray examinations in circumstances of war.

The second part of the book describes the roentgenographic diagnosis according to regions of the skeleton. The book is written in Russian.

The whole subject is treated concisely and, despite the comparatively small size, is well balanced. The illustrations are fairly well reproduced.

Textbook of Surgical Treatment Including Operative Surgery. C. F. W. Illingworth, M.D., Ch.M., F.R.C.S.E., Editor. Ed. 2. Baltimore, The Williams and Wilkins Company, 1944. $9.00.

Throughout the book, emphasis is laid on the preoperative and postoperative care of the patient, as being as important as the operative treatment.

This second edition contains a newly written chapter on "The Treatment of Burns".

Affections of blood vessels, skull and brain, spine and spinal cord, peripheral nerves, bones and joints are considered by systems and in later chapters they are taken up by regions. Amputations, fractures, tuberculosis of bones and joints are discussed in special chapters. The subject matter is well presented and well illustrated. The latest methods of treatment are well summarized.

The various chapters have been written by different surgeons. Each one has presented his own personal ideas, and it is surprising that the editor has accepted some of them. In writing of the treatment of cancer of the breast, the statement is made: "Since recurrence of carcinoma in the skin can readily be prevented by X-ray therapy, it is no longer customary to remove a large ellipse of skin and consequently difficulty in closing the wound is rare". The reviewer suggests that, at least in the United States, this is untrue, and that it is vicious teaching. If British x-ray therapy is so efficient, why should not the timid surgeon forego operating at all, and let the radiologist treat the patient?

Tratamiento de los Traumatismos del Carpo (Fracturas y Luxaciones) [Treatment of Carpal Traumatisms—Fractures and Dislocations.] José A. Sgrosso. Buenos Aires, Aniceto Lopez, 1944.

This booklet of slightly over one hundred pages is based upon the author's observations of 228 cases of injury to the carpus. The work is divided into two main portions. The first deals briefly with the anatomy, the physiology, and the radiology of the bones of the carpus. In discussing the physiology of the wrist, the movements of each of the carpal bones in the various wrist motions are described. Attention is called to the fact that the scaphoid is an intrinsic part of both rows of carpal bones, and that its proximal portion governs the proximal carpal row, and its distal portion, the second row of bones. In discussing radiology, the author stresses the desirability of taking other than the standard anteroposterior and lateral views. The oblique view, with the wrist in 45 degrees of supination, is especially valuable for examining the pisiform and cuneiform bones and the unciform process. The oblique view, with the wrist in 45 degrees of pronation, is valuable for study of the scaphoid.

The second and larger part of the work is dedicated to a rapid review of the fractures and dislocations of the various bones of the carpus. In this recital, lesions of the scaphoid and the perilunar dislocations are naturally given the most consideration. In general, the author's practice seems to be dominated by the reports of American and French surgeons which have already been published.

Unfortunately, little attention is paid to the malaciae, osteoporoses, and other sequelae of injuries of the carpus.

The volume serves a useful function in affording a quick and an accurate review of the subject with a fairly satisfactory bibliography for those who wish to pursue the subject further.

KLINIKA SEPTICHESKICH OSLOJNENIY OGNESTRELNIKH RAN (The Clinic of Septic Complications of Shotgun Wounds). A. V. Melnikov. Moscow, Medgiz, 1943.

The book is written in Russian. It is divided into two parts. The first is dedicated to general pathology, classification, and diagnosis. The second section is devoted to specific problems in the clinical course in definite regions, and to treatment.

The book is of interest, as it apparently presents an approach to the problem of septic infections, used by a large group of surgeons in the U.S.S.R., and especially by the author.

CAMPING FOR CRIPPLED CHILDREN. Edited by Harry H. Howett. Elyria, Ohio, The National Society for Crippled Children and Adults, Incorporated, 1945.

This small volume encourages the universal hope that one day *all* physically handicapped children will have the same rights and privileges enjoyed by physically sound children. Although the struggle is a hard one, and the odds are great, the Society's records show that the camp movement has grown from five camps serving 200 children in 1920, to fifty-six camps serving 3,518 children in 1944.

The National Society for Crippled Children and Adults, recognizing the benefits to be gained by children in summer camps, feels that the special needs of handicapped children can best be met in camps devoted entirely to them. The Society's aims and objectives are clearly set forth. From the choice of a camp site to the careful selection of therapists and technicians, every effort is directed toward helping the crippled child to feel at home in a natural atmosphere, with not the slightest hint of hospital or institution. Stress is laid on a normal life of out-of-door fun, social adjustment, and development of character.

Plans for organization of such camps are set forth in complete detail, and to each chapter there is appended a bibliography for the reader seeking more specific information.

MEDICAL USES OF SOAP. A SYMPOSIUM. Edited by Morris Fishbein, M.D. Philadelphia, J. B. Lippincott Company, 1945. $3.00.

This symposium of articles about soap discusses soap technology, including the chemistry of soap, its manufacture, the new detergents, and detergency or cleansing action; the usual or normal effects of soap on the "normal" skin; its unusual or abnormal effects on the "normal" skin; the effects of soap on the abnormal or diseased skin; its effects on the hair; soaps for industry and the industrial worker; soap for shaving; cutaneous detergents other than soap; and the medical uses of soap.

Nine authors besides Dr. Fishbein have contributed to this symposium. Bibliographies are given for further study concerning the effects of soap on the abnormal or diseased skin; soap for shaving; cutaneous detergents other than soap; and the medical uses of soap.

AMERICAN MEDICAL PRACTICE IN THE PERSPECTIVES OF A CENTURY. Studies of the New York Academy of Medicine, Committee on Medicine and the Changing Order. Bernhard J. Stern, Ph.D. New York, The Commonwealth Fund, 1945. $1.50.

The author discusses the change within a century from a rural to a predominantly urban society, with its concomitant luxuries and conveniences, and what it has meant to medical practice. He contrasts the aids to diagnosis and treatment available to the physician today with the meager equipment of the doctor of the nineteenth century. The gradual growth of medical practice during this period is traced.

Some of the problems considered include the position of the specialist in medicine and that of the general practitioner; trends in the supply and distribution of physicians; the patient load in medical practice; the income of physicians; the distribution of medical services; and the effect of recruiting on the supply of physicians in civilian areas.

This short survey gives many useful statistics and should prove interesting to the reader who wishes a comprehensive picture of the present field of medical practice.

ÜBER MENISCUSGANGLIEN (Cysts of the Menisci). Helge Sjövall. *Acta Chirurgica Scandinavica,* LXXXVII, 561, 1942.

The writer collected twelve cases of cysts of the menisci over a twenty-year period. In ten cases the diagnosis was verified by operation. Seven were in males and five in females. The ages varied from five to sixty-seven. In five cases, the lesion was of the medial, and in seven, of the lateral meniscus. In addition, the writer collected 358 cases from the literature.

From the combined material, he concludes that the lesion is a hyperplastic formation, caused by minor injuries or normal wear and tear of the cartilage tissue. The results with operative removal of the cyst and the cartilage were good. In some of the patients, only the cyst was removed, and these cases were symptom-free at the time of the follow-up examination.—*Walter P. Blount, M.D., Milwaukee, Wisconsin.*

STUDIES ON RECONSTRUCTIVE AND STABILIZING OPERATIONS ON THE SKELETON OF THE FOOT WITH SPECIAL REFERENCE TO SUBASTRAGALAR ARTHRODESIS IN THE TREATMENT OF FOOT DEFORMITIES FOLLOWING INFANTILE PARALYSIS. Snorri Hellgrímsson. *Acta Chirurgica Scandinavica,* LXXXVIII, Supplementum 78, 1943.

In order to determine the effect of different stabilizing and reconstructive operations on the foot in the treatment of foot deformities resulting from infantile paralysis, and of congenital club-foot in adults, all the traceable patients were subjected to follow-up examinations. These patients had been treated by cuneiform tarsectomy, subastragalar arthrodesis, and panastragalar arthrodesis for these deformities at the Stockholm Orthopaedic Clinic between 1928 and September 1941. Treatment included 100 subastragalar arthrodeses, and fifteen panastragalar arthrodeses for infantile paralysis. There were nineteen congenital club feet treated by subastragalar arthrodeses, and twenty by cuneiform tarsectomy. Thirty-three feet, paralyzed as a result of poliomyelitis, were treated by cuneiform tarsectomy. The results are tabulated.

The results with cuneiform osteotomies were not so good as those obtained with the other operative method, because of recurrence due to incomplete correction of the deformity at the operation. Cuneiform osteotomy is indicated in only the isolated deformity of the mid-foot or forefoot in which muscle balance can be obtained by tendon transplantation. Failures of subastragalar arthrodesis were due to one or more of three factors: incomplete correction of the deformity at the operation; imperfect bone consolidation; and defective stability of the ankle joint.

Out of 100 cases of subastragalar arthrodesis, twenty showed imperfect bony union in one or more joints. In four of these, the deformity had recurred. In one there was severe pain due to the pseudarthrosis between talus and navicular. In the remaining patients a firm fibrous ankylosis had occurred, and the non-union was of no consequence. The three factors of most importance in obtaining bone fusion are: adequate age of the patient; the operative technique; and the duration of the effective immobilization. Arthrodesis should not be performed on a patient under eight years of age, and the writer recommends postponing it until the age of fourteen, if possible. The operative technique should include the removal of all cartilage and compact bone, so that good contact is obtained between spongy bone surfaces. Any gap should be filled with bone chips. Immobilization should be continued for ten weeks or more. Of forty feet immobilized for eight weeks or less, 47.5 per cent. had incomplete bony consolidation. Out of ninety-one feet immobilized for ten weeks or longer, there were only 7.7 per cent. with imperfect fusion. If roentgenograms fail to show union at the end of the period of immobilization, immobilization should be extended for another month.

Panastragalar arthrodesis is indicated when there is, in addition to the indication for subastragalar arthrodesis: (1) marked lateral instability of the ankle, (2) degenerative arthrosis of the ankle joint, or (3) irremediable paralysis of the quadriceps femoris combined with paralysis of the foot. The writer prefers the lateral approach of Guildal which is presented in detail. The foot should be placed in 15 to 20 degrees of equinus in most cases. End results of fifteen cases of panastragalar arthrodesis are carefully analyzed. Eight were good and seven, improved. Three, with tender calluses on the balls of the feet, showed malposition.

This monograph on stabilizing operations is notable also for its historical review, its consideration of foot mechanics and anatomy, the bibliography, and the splendid translation into English by Grace Lundberg. It should be studied by every young orthopaedic surgeon.—*Walter P. Blount, M.D., Milwaukee, Wisconsin.*

NAILING IN THE MARROW CAVITY IN CASES OF RECENT FRACTURE AND PSEUDARTHROSIS. Anders Westerborn. *Acta Chirurgica Scandinavica,* XC, 89, 1944.

In 1940, Küntscher first publicly presented his method of fracture fixation with a medullary pin, V-shaped in cross section. Since then, the method has been widely used in Germany. The writer presents the results in twenty-eight cases with fourteen fresh fractures and fourteen non-unions. The latter were mostly from gunshot wounds in Finnish soldiers.

The principle of the method is that of firm internal fixation, following reduction by either open or closed methods of the transverse, spiral, or oblique fractures of long bones. The nail is driven in from an incision far from the site of the fracture. Because the nail is V-shaped, it produces firm fixation without occupying much of the marrow cavity. Several sizes are necessary. In the case of the femur, the nail is inserted through the greater trochanter without further preparation of the cortex. For other long bones it is necessary to make a suitable hole. The writer suggested preliminary insertion of a Kirschner wire as a guide.

In the German literature the writer finds widely divergent opinions as to indications. Most surgeons, including Böhler, agree that the method was useful in gunshot fractures of the long bones. A few were enthusiastic about the use of the method in most fresh fractures particularly in older people, in whom it permits early ambulation.

The writer reports the best results in fractures of the femur. Here the method offers the greatest

benefit. Difficulties were encountered in fractures of the tibia. In the forearm, when the radius was nailed, it was still necessary to apply a plaster cast. Westerborn lists the advantages of nailing in the marrow cavity:

1. Shortened stay in bed;
2. Simplified treatment—no extension;
3. Reduced pain and other subjective troubles;
4. Less risk of stiff joints, muscular atrophy, and circulatory disorder;
5. No postoperative physical therapy;
6. Shorter hospital stay and probable earlier return to work.

The risks are recognized. Two cases of fat embolism have been reported. The likelihood is not great. There is apparently no significant damage to the bone marrow. It is recommended that the nail be removed, when the fracture has healed. Osteitis has developed in some cases, but it has not been serious.

Twelve cases of non-union treated by freshening of the bone ends and intramedullary nailing are reported in detail. The results were apparently excellent. Early weight-bearing was possible in most cases.—*Walter P. Blount, M.D., Milwaukee, Wisconsin.*

A CONTRIBUTION TO THE PATHOGENESIS OF CHONDROMALACIA OF THE PATELLA. Carl Hirsch. *Acta Chirurgica Scandinavica,* XC, Supplementum 83, 1944.

It is interesting to note that most of our recent knowledge of chondromalacia of the patella has come from the Scandinavian countries. Now comes a study of the pathogenesis from a physical, histological, and chemical standpoint. After exacting studies of postmortem and operative material, the writer decides that a nutritional disorder from unfavorable pressure may be one of the main reasons for pathological changes in the cartilage of the patella.

By using autopsy material and an elastometer which he constructed himself, the writer measured the elasticity of the hyaline articular cartilage of the knee joint in different regions. He showed that:

1. Healthy hyaline articular cartilage had a typical elasticity curve.
2. The degree of deformity occurring in healthy cartilage was dependent upon the pressure per unit area and the duration of the loading.
3. Within certain limits, loads of short duration caused no deterioration in the elasticity, but repeated or prolonged loading produced at least a temporary impairment in elasticity.
4. Cartilage could adapt itself functionally to a certain extent to increasing loads of short duration, in that the relative elasticity modulus computed by the author increased with increases in the loads.

Specimens obtained from autopsy and operation were stained with toluidine blue after fixation in basic lead acetate. Healthy patellar cartilage showed variations in the metachromatic staining in the most superficial zones of the cartilage. Malacic cartilage showed distinctly less metachromatic staining in all the zones. Histologically, the latter exhibited a markedly reduced content of chondroitin-sulphuric acid as compared with healthy patellar cartilage. There is always less chondroitin-sulphuric acid in the superficial than in the deeper layers of the cartilage.

By chemical analysis the author showed that the content of sulphur bound to esters was lower in malacic than in healthy cartilage. Comparative elasticity measurements in healthy and malacic cartilage showed that whenever the content of chondroitin-sulphuric acid was reduced, the cartilage also exhibited impaired elasticity. Loss of elasticity means loss of circulation of the tissue juices and impaired nutrition. If abnormal mechanical strains are often repeated, it is likely that the circulation becomes so impaired that the cartilage grows softer and loses some of its chondroitin-sulphuric acid.—*Walter P. Blount, M.D., Milwaukee, Wisconsin.*

ZUR KENNTNIS DER SKELETTVERÄNDERUNGEN BEI KINDLICHER AKUTER LEUKOSE (Information Regarding Skeletal Changes in Acute Leukaemia in Children). Olof Brandberg. *Acta Paediatrica,* XXX, 205, 1942.

Brandberg states the importance of skeletal changes in leukaemia. Chief among such changes are foci of destruction, subperiosteal calcification, and zones of rarefaction. Three case histories are reported in detail. Examination showed that the areas of destruction and the subperiosteal thickening in the bones resulted from leukocytic infiltration. The zones of rarefaction were usually found at the metaphyses, most commonly at the iliac crest and pubic bone. None of these skeletal changes is pathognomonic of leukaemia. They are also commonly found in osteomyelitis and polyarthritis.—*John G. Kuhns, M.D., Boston, Massachusetts.*

KANN DE PLATTFUSS IM KINDESALTER OHNE EINLAGEN EFFEKTIV BEHANDELT WERDEN (Can Flat-Foot in a Child be Effectively Treated without Confining the Child in Bed)? J. Nordenfelt. *Acta Paediatrica,* XXX, 94, 1942.

Nordenfelt states that among children in Sweden flat-foot is an extremely common deformity, and

is frequently the cause of pain and disability. It is a different type of deformity from that found in adolescents. It consists chiefly of a failure or weakness of the ligamentous structures and muscles. Such feet should not be constricted by shoes and stockings. The child should be given an opportunity to strengthen his foot muscles. Forty children were given daily exercises for the feet for from three to nine months. Thirty-one children were considered cured, and the other nine were improved. No foot supports were used. Photographs are shown of ten patients before and after treatment.—*John G. Kuhns, M.D., Boston, Massachusetts.*

BEITRAG ZUR PATHOLOGISCHEN ANATOMIE DER ARACHNODAKTYLIE (Investigation of the Pathological Anatomy of Arachnodactilia). C. G. Bergstrand. *Acta Paediatrica,* XXX, 345, 1943.

Arachnodactilia is a relatively rare condition about which little has been reported. Bergstrand reports the case history and postmortem examination of a female infant suffering from arachnodactilia. Death was due to bronchopneumonia. The only abnormal findings were a single lobe in the left lung and absence of the dilator pupillae in both eyes. Microscopically, no abnormal findings were observed in the bones, connective tissue, musculature, or endocrine glands. In the literature, Dupuytren-like contractures have been reported, and it has been mentioned that the bones grew more rapidly than the connective tissue. After reviewing the theories which have been advanced to explain this deformity, the author concluded that it appeared to be a mesodermal dystrophy.—*John G. Kuhns, M.D., Boston, Massachusetts.*

ISOLIERTE FRACTUREN DER ERSTEN RIPPE (Isolated Fractures of the First Rib). S. E. Sjögren. *Acta Radiologica,* XXIII, 79, 1942.

Five cases of isolated fractures of the rib are reported. In the author's opinion, this fracture is more common than is believed. Because of the difficulty of roentgenographic demonstration, the lesion may be overlooked.

The fracture may arise as a result of: (1) indirect trauma through the clavicle; (2) direct trauma from behind; (3) indirect trauma from the manubrium; (4) contracture of the scalenus muscle.

The clinical symptoms are always indefinite. Usually the patient complains of pain in the shoulder. This is made worse by motion of the head or arm, but not by deep breathing. This fracture may be complicated by injury to the underlying subclavian vessels, the brachial plexus, or the lung. Healing is usual, but pseudoarthroses are occasionally seen.—*Henry Milch, M.D., New York, N. Y.*

ZWEI NEUE FÄLLE MIT "STREIFENFÖRMIGER OSTEOPOIKILIE" (VOORHOEVE) [Two Cases of the Streaky Form of Osteopoikilosis (Voorhoeve)]. Åke Lindbom. *Acta Radiologica,* XXIII, 296, 1942.

Osteopoikilosis is a hereditary skeletal anomaly first described by Albers-Schönberg in 1915. Roentgenographically it appears in two forms, (1) the more common spotty form, and (2) the unusual streaky form described by Voorhoeve in 1924.

The former occurs in the metaphyses and epiphyses of the long bones, the tarsalia, the carpalia, the pelvis, and the shoulder girdle. The latter is found in the metaphyses of the long bones close to the epiphyseal line at points where endochondral ossification occurs.

In addition to the two cases originally described by Voorhoeve, two cases were described by Mascherpa in 1931. Two additional cases are presented by Lindbom. As in the earlier cases, the two here reported occurred in a brother and sister. In both the condition caused no symptoms and was an accidental discovery. In both the skin condition known as dermatofibrosis lenticularis disseminata was present.

The presence of the skin lesion strengthens the belief in relationship between the spotty and streaky forms of osteopoikilosis.—*Henry Milch, M.D., New York, N. Y.*

TUBEROUS SCLEROSIS WITH CHANGES IN LUNG AND BONES. E. Samuelson. *Acta Radiologica,* XXIII, 373, 1942.

The author reports the case of a female aged forty-nine whose clinical course began at the age of thirty-six years with hemoptysis. A diagnosis of mitral stenosis made at this time was later changed to pulmonary tuberculosis, then to chronic miliary tuberculosis, and finally to Boeck's sarcoid. Roentgenographically, the patient presented the signs of bilateral miliary infiltration of the lungs. The hands "showed periosteal thickening on the metacarpal bones and in the fingers, both some opacities and some osteoporosis with cyst-like rarefactions".

In June 1941 the patient died of cerebral hemorrhage and the postmortem examination disclosed: "(1) irregular, nodular, or tuberous sclerosis in the lungs with small-cystic pulmonary degeneration; (2) sequelae after an old endocarditis and a parietal thrombus in the heart; (3) multiple benign tumors in both kidneys; (4) tuberous sclerosis of the brain, two small tumors in the choroid plexus and multiple brain infarcts with hemorrhage and emollition; (5) roentgenographically demonstrable changes in both hands". No signs of tuberculosis or Boeck's sarcoid were found.

Bone changes have been reported in the cranium as well as in the hands and feet. "Whether these changes are possibly due to small fibrous or similar small, benign tumors in the periosteum and bone

marrow is probably not known, inasmuch as it does not seem that any patho-anatomic examination has been made of the hands."

It is the opinion of the author that the tuberous sclerosis of the lungs, bone changes, the tumors of the kidney, and the brain condition are all part of the heterogeneous picture of tuberous sclerosis.—*Henry Milch, M.D., New York, N. Y.*

PRIMARY BONE SARCOMA. Reidar Eker and Erik Poppe. *Acta Radiologica*, XXIII, 387, 1942.

Among 3,795 patients treated for malignancy at the Norwegian Radium Hospital, forty-two suffered from primary sarcomata of bone. These were classified as follows: In the osteogenic series, were eighteen cases of osteoblastic tumors, and four cases of osteolytic tumors; in the chondroma series were seven cases of chondrosarcoma, and three cases of myxochondrosarcoma; there were five cases of Ewing's sarcoma; four cases of periosteal fibrosarcoma; and one case was a non-classifiable sarcoma.

All but one of the patients were given protracted fractioned roentgenotherapy. This consisted of a total of 12,000 to 13,500 roentgen units. In some cases, a second series of half the dosage was given after a lapse of from three to four months.

The authors call attention to the fact that of the twenty-two cases of osteogenic sarcoma, thirteen were localized to the metaphyses around the knee joint. In twelve, there was a history of trauma in the tumor region. These traumata occurred from two weeks to two years before the onset of symptoms. In five cases there was a history of continuous symptoms following injury. Pain is usually the first symptom.

The osteoblastic form occurs mainly in the young-age group; the osteogenic type in the older-age group. In both, the prognosis seems to depend upon the histology of the tumor. "In our opinion combined surgical and radiological treatment should be administered for osteogenic sarcomata. By beginning with radiological treatment a basis can be established for the tumors' radiosensitivity. If the tumor belongs to a type of low histological malignancy, and proves to be rather radiosensitive, there is a possibility that operation may be avoided or carried out with retention of the function of the limb."

In general, the prognosis is not good, although three patients are alive and healthy more than five years after the first treatment. The average length of life is not quite twenty-one months after the first treatment, or a little more than twenty-five months after the onset of symptoms.

Roentgen treatment had little or no effect on the cases of myxochondrosarcoma. In five of six cases of chondrosarcoma, there appeared to be subjective improvement.

Ewing's tumor is extremely sensitive to roentgenotherapy, and the five cases which the authors studied were given roentgen treatment exclusively. Four of the patients died within three to fourteen months after the first treatment. One patient is alive and free from symptoms after five years.

For periosteal fibroblastic sarcoma, surgery is considered the most important form of therapy. Resection of the tumor followed by radiation therapy is a procedure which seems satisfactory.—*Henry Milch, M.D., New York, N. Y.*

VOLUM- UND FORMVARIATIONEN DES WIRBELKANALS BEI LORDOSIERUNG, BZW. KYPHOSIERUNG UND IHRE BEDEUTUNG FÜR DIE MYELOGRAPHISCHE DIAGNOSTIK (Variations in Form and Volume of the Spinal Canal in Lordosis and Kyphosis; Its Significance in Myelographic Diagnosis). Folke Knutsson. *Acta Radiologica*, XXIII, 431, 1942.

Myelographic diagnosis is based upon extradural deformation of the dural sac. The dural sac is separated from the wall of the spinal canal by a slight amount of loose connective tissue, and in consequence its contour is dependent upon the outline of the spinal canal.

In order to determine the influence of each of these elements, the author studied cadaver and living specimens fixed in lordosis and kyphosis. He was able to show that there was a definite decrease in the volume of the canal when the spine assumed the position of lordosis. In this attitude three factors are noted: (1) the ligamenta flava become shorter and thicker, and by bulging into the canal they reduce its volume; (2) the intervertebral notches become smaller because the superior articular facets are rotated forward; and (3) the intervertebral disc bulges backward into the vertebral canal.

Since the nerves course along the anterior wall, they occupy a greater portion of the narrowed (lordotic) spinal canal than of the kyphotic canal. As a consequence the defect in the column of the contrast medium is greater in lordosis than in kyphosis.—*Henry Milch, M.D., New York, N. Y.*

ASEPTIC NECROSES IN THE EPIPHYSES OF DIGITAL PHALANGES AND METACARPAL BONES (THIEMANN'S DISEASE; DIETRICH'S DISEASE). Sigurd Franck. *Acta Radiologica*, XXIII, 449, 1942.

The author presents the case of a young man, eighteen years old, who complained of pains in his fingers. The symptoms had begun three to four years previously, without any history of trauma. Objectively there was slight restriction of mobility with swelling of the affected joints. Roentgenographically there was found flattening, irregular bony sclerosis, cup-shaped broadening of the basal epiphyses, and fragmentation and sequestration in the epiphyses.

The diagnosis is made on the basis of the roentgen changes. When healing occurs, the symptoms recede. Treatment is always symptomatic.

The condition may affect both the phalanges and the metacarpals (described by Thiemann in 1909), or only the metacarpals (described by Dietrich in 1932).—*Henry Milch, M.D., New York, N. Y.*

HEMANGIOMA OF THE CERVICAL VERTEBRA WITH FRACTURE AND COMPRESSION MYELOMALACIA. Olav Holta. *Acta Radiologica,* XXIII, 423, 1942.

Hemangioma of the vertebra occurs in approximately 10 to 12 per cent. of all spines. Schmorl and his associates, examining 2,154 spines, found 257 instances, or 11.93 per cent. Junghanns found 409 hemangiomata in an examination of 3,829 spines. Of these, 350 occurred in the thoracic spine, 170 in the lumbar spine, thirty-two in the cervical, and twenty-seven in the sacral areas. Generally speaking, women are more frequently affected than men, and more than half develop in people under the age of thirty.

The hemangiomata are found mainly in the body of the vertebra, but may affect the arch. Clinically these hemangiomata give rise to symptoms of transverse myelitis when they reach the surface of the bone, and cause a compression of the underlying spinal cord. This may be due to: (1) propagation of the hemangioma into the spinal cord; (2) compression through thickening of the corpus and the arch; (3) compression fracture of the vertebra; (4) epidural hemorrhage.

Roentgenographically these tumors appear as rarefactions of the spongiosa with longitudinal thickening of the trabeculae. In the arches, hemangiomata may present the appearance of an irregular network.

Treatment may be either surgical or by radiation. Where definite compression symptoms exist, laminectomy may alleviate the medullary pressure.

The author reports a case in which a compression fracture of the fourth cervical vertebra, the site of a hemangioma, took place. The patient developed symptoms of a complete transverse lesion at the level of the fourth cervical vertebra, and died despite roentgenotherapy.

Autopsy revealed a typical hemangioma of the fourth cervical vertebra with compression of the body. Examination of the spinal cord disclosed a myelomalacia at the level of the vertebral lesion.—
Henry Milch, M.D., New York, N. Y.

TWO CASES OF SYMPATHICOBLASTOMA OF THE SUPRARENAL GLAND WITH METASTASES TO THE CRANIUM AND THE TUBULAR BONES. Thomas Rosendal. *Acta Radiologica,* XXIII, 462, 1942.

The author reports two cases of sympathicoblastoma. These tumors usually occur in children below the age of two. They are characterized by metastases to the cranium, especially about the orbits, and are typically associated with exophthalmos and hemorrhages into the eyelids. In the cranium, the metastases show small spotted destruction; in the long bones, they show large spotted destruction.

The cranial changes may resemble Hand-Schüller-Christian syndrome, Ewing's sarcoma, lues, chloroma, and leukaemia. Roentgenotherapy has only a temporary effect. As a rule the lesion is fatal. A single case has been described in which the patient was still alive fifteen years after operation.—*Henry Milch, M.D., New York, N. Y.*

ASEPTIC BONE NECROSIS OF THE OS CAPITATUM (OS MAGNUM). Gunnar Jönsson. *Acta Radiologica,* XXIII, 562, 1942.

The author reports a case of aseptic necrosis of the capitate bone, occurring in a nurse twenty-two years old. There was no previous history of trauma. The patient complained of pain, weakness, and occasional swelling. There were no signs of inflammation, but crepitus was noted on motion of the wrist. The x-ray showed typical progressive fragmentation, sclerosis, and compression of the capitate bone.

It is believed that this hitherto undescribed condition resembles that found in the os lunatum. The process has not become completely quiescent, and ultimately an osteo-arthritis of the wrist may be expected. No indication for therapy is given.—*Henry Milch, M.D., New York, N. Y.*

ROENTGENOLOGICAL EARLY SYMPTOMS AND HEALING PHENOMENA IN CHRONIC RHEUMATIC ARTHRITIS. Folke Knutsson. *Acta Radiologica,* XXIV, 121, 1943.

The author has had the opportunity of studying cases of rheumatoid arthritis over prolonged periods of time. He is of the opinion that early diagnosis can be made roentgenographically from studies of the hands and feet. These two appear to be the sites of predilection in the early phases of the disease.

In this phase the roentgenograms are characterized by articular decalcification, especially in the metatarsophalangeal or metacarpophalangeal joints. Juxta-articular periostitis is quite typical, and is apparently present only in the florid stage of the disease. The author does not believe that increase in width of the joint due to effusion is commonly seen.

On the contrary, narrowing of the joint space as a result of destruction of the cartilage is typical of the second stage. So-called "ulceration" or destruction appears mainly in the head of the fifth metatarsal. Such ulcerations, however, appear elsewhere.

The third or healing stage is characterized by replacement of the irregular contour of the ulcerations by a smooth, even outline. In those cases in which the cartilage has disappeared entirely, fusion of the joint takes place. The author suggests that in evaluating the effects of therapy, the roentgenographic changes should be noted.—*Henry Milch, M.D., New York, N. Y.*

Some Experiences with a New Method of Arthrography. Kjeld Andersen. *Acta Radiologica,* XXV, 33, 1944.

The author comments upon the difficulty of obtaining satisfactory arthrograms in conditions affecting the menisci. In the method which he recommends, N_2O is used as a contrast medium. After appropriate sterilization, the skin is anaesthetized with five cubic centimeters of 0.5 per cent. novocaine. Using the technique and instrumentarium of Tischendorff sixty to one hundred cubic centimeters of N_2O is injected into the knee joint.

The patient is then placed in the prone position, and the knee is flexed, abducted, or adducted until optimum views as determined by the fluoroscope are achieved. Eight to ten roentgenograms are made in different positions. The method has been used in fifty-two cases. The roentgenograms which are reproduced are really so clear that even untrained observers can recognize the lesion. The method seems worthy of trial.—*Henry Milch, M.D., New York, N. Y.*

Common Congenital Anomalies of the Bony Thorax. L. K. Sycamore. *The American Journal of Roentgenology and Radium Therapy,* LI, 593, 1944.

The author studied chest roentgenograms of 2,000 freshmen entering Dartmouth College. Congenital anomalies of the bony thorax occurred in 2.8 per cent. of the students. There were twenty cases of bifurcation of the ribs, ten cervical ribs, ten rudimentary first ribs, six cases showing flaring of the anterior end of the rib, six cases where two ribs were fused, and four cases where there was bridging between two ribs. Calcification of the first costal cartilage was found in 4 per cent. of the college freshmen, who averaged nineteen or twenty years of age, but a series of 100 roentgenograms of medical students three or four years older showed calcification in a greater or lesser degree in 42 per cent.

Evidence is presented which suggests that the appearance, described by various authors as fracture of the first rib, may in some cases be due to a congenital anomaly.—*E. A. Cobb, M.D., Iowa City, Iowa.*

Osteochondritis of the Capitellum (Panner's Disease). Herman C. March. *The American Journal of Roentgenology and Radium Therapy,* LI, 682, 1944.

The author reviews the literature concerning osteochondritis of the capitellum and finds that, since Panner first described this site of osteochondritis, very few cases have been presented. He presents one case. Good roentgenograms accompany the case history.—*E. A. Cobb, M.D., Iowa City, Iowa.*

Traumatic Separation of the Upper Femoral Epiphysis. A Birth Injury. Putnam C. Kennedy. *The American Journal of Roentgenology and Radium Therapy,* LI, 707, 1944.

The author reviews from the literature twenty cases of traumatic separation of the upper femoral epiphysis, and adds one case of his own. Every case except one in the literature occurred during podalic version and breech extraction, or breech presentation and extraction. In the author's case, the position was occipitoposterior, delivery was by low forceps, and no known trauma was exerted on the legs. The author states that at birth the upper femoral epiphysis is a single cartilaginous mass, including head, neck, and both trochanters. In traumatic separation, it is displaced medially and downward at its junction with the diaphysis. The periosteum is usually stripped up and sometimes ruptured. The joint capsule and ligamentum teres femoris remain intact. Rotary movements combined with traction on the leg are necessary to produce the injury. The clinical signs are swelling, slight shortening, limitation of active motion, painful passive motion, and external rotation; and occasionally discoloration, crepitus, abduction or adduction.

The roentgenographic signs are displacement of the proximal end of the diaphysis, upward and outward; rapid, profuse callus formation and prominent subperiosteal reaction around the upper end of the shaft; absorption of callus and reconstruction of the femoral neck; and premature ossification of the capital epiphysis and accelerated growth of the femoral neck on the injured side.

The prognosis is good in cases of milder injury, but rather poor when the initial trauma and displacement have been severe. Coxa vara is a frequent end result in the latter group of cases.—*E. A. Cobb, M.D., Iowa City, Iowa.*

Primary Hemangiomatous Tumors of Skeletal Muscle. Thomas A. Shallow, Sherman A. Eger, and Frederick B. Wagner, Jr. *Annals of Surgery,* CXIX, 700, 1944.

This is an extensive and complete article dealing with the subject of primary hemangiomatous tumors of skeletal muscle. The authors make an analytic review of 333 cases in the literature and add two cases of their own.

The practical conclusions of the study of these tumors are as follows:

1. The lesion is of the diffuse type in most cases.
2. There are no proved cases of metastasis from a primary muscle hemangioma, although malignant degeneration has been reported as probable in a few instances.
3. In treatment the procedure of choice is early complete surgical excision, well beyond the confines of the tumor. This was the treatment used in 79 per cent. of the cases, with improvement or cure in 90 per cent. If malignant degeneration is suspected, deep postoperative roentgenotherapy is advocated.
4. There was no surgical mortality for the entire series. Local recurrence or lack of improvement was reported in 6 per cent. Postoperative deformity resulted in 4 per cent.

The authors favor the view that hemangiomata are congenital tumors, originating from abnormal embryonic sequestrations of vascular tissue. Trauma and systemic infection, acting as secondary factors, may modify subsequent growth and clinical manifestations.—*Jose Puig Guri, M.D., Iowa City, Iowa.*

A PHYSIOLOGIC ANALYSIS OF THE NATURE AND OF THE TREATMENT OF BURNS. William W. L. Glenn. *Annals of Surgery*, CXIX, 801, 1944.

Attention is directed to this article because of its possible importance with regard to the exudate which forms in the soft tissues in fractures. In burns it was found that the exudate clotted and formed a stagnant gel which acted as a foreign body. This gel was slowly absorbed, and its complete removal was necessary before healing took place. It formed a source of nitrogen for the proliferation of fibroblasts with ultimate scarring. For these reasons, it was decided that restriction of the exudate is imperative in all burns. Perhaps further study of this subject will show an analogy or even a similarity between the gel which forms in burns and the state of the exudate which forms in fractures. If this is demonstrated, there will be good reason for attempting to limit the exudate in fractures even as in burns.

Glenn found that closed plaster encasements, gently molded over a minimum of gauze padding, and extending entirely over the end of the extremity, were effective in restricting the exudate. No local harm resulted from this treatment. It is strongly emphasized that no external pressure is used in applying the plaster. As plasma escapes from the dilated capillaries, the pressure which the extravascular tissue fluid builds up against the plaster encasement is exactly equal to the pressure attempting to push fluid out of the capillaries. When this pressure equilibrium is reached, no more fluid can leak out than can be carried off by the lymphatics or can be absorbed by the capillaries.—*Paul P. Swett, M.D., Bloomfield, Connecticut.*

EXTERNAL PIN TRANSFIXION OF FRACTURES. AN ANALYSIS OF EIGHTY CASES. Irwin E. Siris. *Annals of Surgery*, CXX, 911, 1944.

In view of the enthusiastic reception given to the various ingenious devices which make it not only possible but tempting to employ external pin fixation in the reduction and immobilization of fractures. this paper sounds a timely note of warning. This warning is all the more insistent, since it comes from the teaching department of a large metropolitan hospital.

On the basis of a careful analysis of the results in eighty cases treated by external pin fixation, it is concluded that the method should not be used routinely, but should be restricted to selected cases, and then should be employed only by surgeons trained in the technique. The reasons for these conclusions lie in the reported results: discharge from the pin sites in thirty-seven out of eighty cases; osteomyelitis at the pin sites, with discharge persisting long after the fracture had united in eighteen cases; death in eight cases. Delay in union was more common, and seemed to result from the frequent distraction of the fragments.

It is believed that the use of external pin fixation is desirable in persistently displaced compound fractures, and in certain problem fractures. But it is also the author's belief that too much emphasis has been given to the desirability of ambulation, and to constant joint motion; neither of these is an adequate reason for the general employment of external pin fixation.—*Paul P. Swett, M.D., Bloomfield, Connecticut.*

FASCIAL SLINGING OF THE SCAPULA AND CLAVICLE FOR DROPPED SHOULDER AND WINGED SCAPULA. G. C. Dorling. *The British Journal of Surgery*, XXXII, 311, 1944.

The first patient suffered from a winging of the right scapula. This injury followed artificial respiration, given during an operation when he stopped breathing. Two attempts to repair the damaged long thoracic nerve had been made without success.

Very ingenious fascial slings were made, which suspended the scapula to the spinous processes of the sixth cervical and the third thoracic vertebrae. The approach was made by an incision from the fifth cervical to the fifth thoracic vertebrae, just to the left of the midline. A large skin flap was turned back. Holes were bored in the scapula half way between its spine and the upper border, and strips of fascia were threaded

through and carried over the spinous processes. An abduction plaster was applied, and the patient now suffers no disability. He is at present a physical-training instructor.

The second patient was a woman of forty-four who suffered a paralysis of the spinal accessory nerve during an operation for tuberculous glands of the neck Two previous operations had been only partly successful Due to paralysis of the trapezius muscle the entire shoulder girdle drooped. The author suspended the scapula from the sixth cervical vertebra by a fascial strip with very gratifying results —*Ernest M. Daland, M.D , Boston, Massachusetts.*

THE PROBLEMS AND PRINCIPLES OF THE RESTORATION OF LIMB FUNCTION FOLLOWING INJURY, AS DEMONSTRATED BY HUMERAL SHAFT FRACTURES F S A Doran *The British Journal of Surgery,* XXXI, 351, 1944

The cause of joint stiffness may be articular in origin, in which case it may be due to a bony obstruction caused by the displacement of the articular elements, or to shortening of the capsule, possibly with the formation of inelastic pericapsular fibrous adhesions The cause of the stiffness may be muscular in origin This may be due to lack of power to contract because of intramuscular fibrosis, to binding of the muscle to the bone by scar tissue, to gross destruction of muscle tissue, or to paralysis of the motor nerve

Fractures from flying accidents are usually comminuted They are slower to unite, and give more joint stiffness than those caused in accidents from other causes The results in the latter group are twice as good as in the former The amount of joint disability depends on the site of fracture as well as on the mode of injury

In this group of seventy-six cases of fracture of the humeral shaft, all patients who regained full elbow movement did so in eight weeks or less

The writer accepts the Roux theory that more vigorous exercise not only alters the qualitative composition of the muscle, thereby raising its specific efficiency, but also enlarges the muscle in those dimensions only which yield greater activity to the given function. He, therefore, advocates the early use of Swedish resistance exercises to restore power and joint mobility, and the later use of the Danish type of exercise to give speed and coordination —*Ernest M Daland, M.D , Boston, Massachusetts.*

THE RESULT OF OPERATIVE REPAIR OF SEVERE ACROMIO-CLAVICULAR DISLOCATION. A. N. Birkett *The British Journal of Surgery,* XXXII, 103, 1944

This is the record of a man of twenty-nine, injured by being crushed between two lorries. Roentgenograms showed wide separation of the acromioclavicular joint, and it was believed that the outer end of the clavicle was buried in the trapezius Closed reposition was impossible.

Open operation was carried out, and the dislocation was reduced A strip of fascia lata was passed through a hole bored in the clavicle, under the coracoid, over the clavicle, through a second hole near the acromioclavicular joint, and out through a third hole in the acromion. The two ends of the fascial strip were sutured on the upper surface of the clavicle.

Roentgenograms showed a mild degree of subluxation still present Recovery was rapid Check-up roentgenograms showed calcification along the fascial tracts between the coracoid and the clavicle. There was some restriction of motion —*Ernest M Daland, M D , Boston, Massachusetts*

AN UNUSUAL DISLOCATION OF THE FOOT E W. Dorrell *British Medical Journal,* II, 12, 1944.

The author reports an uncommon dislocation of the foot, sustained when the front wheel of a gun-trailer slowly rolled backward over the patient's left foot, from the medial to the lateral side

Roentgenograms showed the cuboid and cuneiforms had been squashed together, and the base of the second metatarsal forced out of its mortise The metatarsals had been forced laterally, the fifth completely dislocated, the second, third, and fourth being subluxated laterally to a lesser degree The cuneiform clinically was very prominent on the medial side of the foot

Reduction was accomplished, under anaesthesia, without traction, by pressure medially on the base of the fifth metatarsal, and laterally on the first cuneiform A surface wound on the anteromedial side of the foot was sutured, and a short unpadded leg plaster applied After twelve days, this plaster was replaced by another for a period of four weeks A walking-iron was then used, and weight-bearing was allowed After eight weeks from the date of injury, the plaster was removed altogether Now, three months after the accident, the patient is walking, and has full painless movement at the ankle joint; inversion and eversion are almost normal

FRACTURES OF THE WRIST AND HAND H S Morton *The Canadian Medical Association Journal,* LI, 430, 1944

The author reviews thirty-two cases of fracture of the carpal scaphoid In twenty-three, the injury resulted from a fall

Treatment consisted of immobilization in a cast, incorporating the joints above and below the injury, for three or four months Firm union resulted in nineteen cases Bone-grafting was used in ten

fractures that failed to unite. A bone graft, one-quarter of an inch in diameter, united the fragments in nine of the ten cases. The author advises against whole or partial excision of the scaphoid, because of resulting residual pain and loss of power. In one case, where drilling and partial excision were used, non-union of eighteen months' duration occurred.

In the treatment of fractures of the metacarpals, two methods were employed: (1) the use of the femoral bone clamp for reduction, and (2) a trapezium fixation by transverse pins, using the adjacent metacarpal as the fourth side of the geometrical figure.

In compound fractures of the phalanges, careful reduction and early movement are invaluable. Longitudinal pinning, by means of an intramedullary wire, was used successfully by the author.

THE OPERATIVE TREATMENT OF INJURIES TO THE SEMILUNAR CARTILAGES IN PERSONNEL OF THE BRITISH AIR FORCES. D. M. Meekison. *The Canadian Medical Association Journal*, LI, 517, 1944.

The author discusses the importance, in the operative treatment of injuries to the semilunar cartilages (menisci) of the knee joint, of (1) correct diagnosis, (2) absence of arthritic changes, (3) the age of the patient, and (4) the adequate and rapid removal of the torn meniscus.

In examining a knee joint for internal derangement, the author looks for the presence of atrophy of the thigh; the presence or absence of fluid in the joint, and of local heat on palpation; springy resistance at 20 or 15 degrees from complete extension (suggestive of a complete bucket-handle lesion); stability of the collateral ligaments tested in extension, and of the cruciates tested at about 100 degrees; points of tenderness around the joint line, and at the attachments of the collateral ligaments with the knee at 90 and 100 degrees; and evidence of posterior herniation in the popliteal space.

The prognosis is poor where arthritis is present in the knee joint, or if the patient is not young. The author avoids operation in a patient over the age of forty, or at most forty-five.

At operation, the incision is well out from the patella, bordering on the tibial collateral ligament. The fascia and the capsule are separated, are incised separately, and the joint is opened from above downward. All articular surfaces are examined carefully. The whole cartilage is removed. If necessary, a posterior incision is made to obtain the posterior horn. The capsule is lightly tacked with interrupted catgut, allowing any effusion to leak through the capsule and be absorbed.

The postoperative dressing includes cotton wool wrapped around the joint, and two elastic bandages, the second a compression bandage, to be removed twenty-four hours later. The patient is allowed up after ten days. Quadriceps exercises are carried out before and after the operation. Results are excellent in nine out of ten cases.

Although final end-result figures have not been obtained by the author, a general and informal survey of some thousands of cases produced a figure of 93 per cent. returned to full duty after seven weeks.

INFECCIONES AGUDAS DE LA MANO (ACUTE INFECTIONS OF THE HAND). Luis Raul Flores. *Cirugia y Cirujanos*, XII, 209, 1944.

This is a long and detailed article dealing with the subject of hand infections, and emphasizing the importance of taking such infections seriously. The author has followed the ideas of Kanavel and Koch, and he feels that surgery performed on the hand should be treated as major surgery, frequently requiring more judgment than abdominal surgery. Only a surgeon of experience should treat infections of the hand. The article points out that the hand has six major spaces where pus can accumulate: dorsal subcutaneous, dorsal subaponeurotic, hypothenar, thenar, interdigital, and mid-palmar. The direction of travel of infections of the various fingers is described. There are two main soft-tissue infections in the hand: lymphangitis and tendon-sheath infections. The generalized nature of the swelling and lack of point tenderness are characteristic of lymphangitis. Tenosynovitis shows exquisite point tenderness, flexion of the finger, pain on extension, and a diffuse swelling involving the finger only. The importance of correct incisions in infections of the hand is stressed. The entire subject is well and accurately covered in this article, which is profusely illustrated.— *Major Louis W. Breck, M.C., Camp Swift, Texas.*

THE SIGNIFICANCE OF MUSCLE SPASM IN THE ACUTE STAGE OF INFANTILE PARALYSIS BASED ON ACTION CURRENT RECORDS. R. Plato Schwartz, Harry D. Bouman, and Wilbur K. Smith. *The Journal of the American Medical Association*, CXXVI, 695, 1944.

After establishing the firm foundations upon which rests the so-called orthodox concept of infantile paralysis, and quoting from the originator of the "new Kenny" concept, the authors again investigated the characteristics in the neuromuscular mechanism in the acute stage of infantile paralysis, in normal individuals and in patients with spastic paralysis. They paid particular attention to muscle spasm. From their data the following points were established:

"1. In some patients spasticity has been recorded in all muscles . . . investigated.

"2. Evidence of spasticity has been recorded from (a) weakened muscles, (b) the antagonists of weakened muscles and (c) muscles which exhibit no clinical or other evidence of weakness.

"3. The evidence does not support the view that fibrillation or inflammation of the muscle is responsible for the spasticity.

"4. On stretching the antagonist of a weakened muscle, the evidence of spasticity in the weakened muscle is frequently greater than the recorded reaction of the muscle in response to voluntary contraction.

"5. On stretch reflex of a weakened muscle, spasticity not only is recorded from its antagonist but also is significantly present in records of the corresponding muscles of the opposite extremity.

"6. In association with voluntary contraction efforts this spasticity spread was recorded from the same group of muscles as resulted from stimulation by stretch reflex noted in 5.

"7. But a muscle which shows no clinical evidence of weakness always produces a stronger voluntary contraction record than the recorded evidence of muscle spasm.

"8. There has never been recorded evidence of spasm when a muscle failed to produce a record of reaction to the voluntary movement.

"9. Spasticity is a generalized phenomenon in the early stages of infantile paralysis.

"10. As prevailing spasm diminished in a weakened muscle, there was recorded evidence of increased strength in the voluntary contraction.

"11. The gross initial spasm of neck and back muscles, so characteristic with onset of the acute stage, invariably disappears without evidence of muscle weakness or paralysis.

"12. There was no correlation between the degree of spasm and the incidence of muscle weakness or paralysis."

In summary of their discussion, the authors state that "certain functional abnormalities other than muscle weakness were observed in the lower reflex arc. They could be most readily explained in terms of a dysfunction at or proximal to the dendrites or cell body of the lower motor neuron. This dysfunction resulted in a partial isolation of the lower motor neuron from the inhibition normally induced by other levels through long and short neural pathways. The degree of lower reflex arc isolation thus established and the degree of viability remaining in the lower motor neurons therefore determined the amount of muscle spasm in each instance.

"Without the involvement of levels proximal to the lower motor neuron there would be no spasm, but the muscle could be either weak or normal, dependent on the number of normal motor neurons innervating the muscle.

"If all motor neurons failed to be stimulated by the stretch reflex there would be no reaction to the stretch reflex even though relationships proximal to the dendrites were normal.

"Spasticity and weakening are two separate phenomena, each dependent on specific disturbances of functions of the anterior horn cells.

"There was every indication that spasm ran its course like other clinical manifestations of the disease.

"The relationship between muscle tenderness and muscle spasm has not been clarified by the work thus far done. . . .

"We have emphasized the clinical phenomena and the electromyographic evidence which indicates that muscle spasm does not initiate the development of muscle weakness."

This article is well organized and is worthy of careful and repeated study by all orthopaedic surgeons interested in anterior poliomyelitis.—*Brandon Carrell, M.D., Dallas, Texas.*

THE ROENTGENOLOGY OF OSTEOMYELITIS. J. W. Pierson and J. F. Roach. *The Journal of the American Medical Association,* CXXVI, 884, 1944.

The authors summarize in a concise fashion the present knowledge of the pathology and associated roentgenographic findings of acute and chronic osteomyelitis. From a roentgenographic point of view, there are three groups of diseases which frequently cause differential difficulties: (1) other infections; (2) bone tumors; and (3) diseases of the reticulo-endothelial system. Syphilis and tuberculosis of the long bones are the two most troublesome infections, and often they cannot be differentiated without additional clinical information. Especially difficult is the differential diagnosis of such bone tumors as osteogenic sarcoma, Ewing's endothelioma, and the metastasis of neuroblastoma. The diseases of the reticulo-endothelial system which cause difficulty are the leukaemias, the lymphomata, the xanthomata, and the congenital anaemias. The characteristic roentgenographic picture of any one of these diseases is usually readily differentiated from the others and from osteomyelitis, but each may have a stage in its development when one sees the picture of osteomyelitis.—*H. H. Beckering, M.D., Dallas, Texas.*

PERSISTENCE OF VIRUS EXCRETION IN THE STOOLS OF POLIOMYELITIS PATIENTS. Dorothy M. Horstmann, Robert Ward, and Joseph L. Melnick. *The Journal of the American Medical Association,* CXXVI, 1061, 1944.

The authors undertook a study to determine the average duration of excretion of poliomyelitis virus in stools of patients following acute infection, and to ascertain whether a chronic carrier state similar to

that occurring in typhoid exists in poliomyelitis. After studying the excretion of poliomyelitis virus in the stools of sixty-one patients, it was found that in sixty-one per cent. the virus was excreted during the first two weeks after onset of the disease, in 50 per cent. during the third and fourth weeks, in 27 per cent. at the fifth and sixth weeks, and in 12.5 per cent. at the seventh and eighth weeks. After the ninth week, virus was detected in only one of fifty-two specimens tested; this had been excreted in the twelfth week. Not one of the sixty-one patients followed was demonstrated to have become a persistent carrier of poliomyelitis virus.—*Brandon Carrell, M.D., Dallas, Texas.*

Pneumococcic Arthritis. Report of Case of So-Called Primary Pneumococcic Arthritis. William P. Boger. *The Journal of the American Medical Association,* CXXVI, 1062, 1944.

The author regards pneumococcic arthritis as a manifestation of a septicaemia, even in those cases in which the primary focus from which the organism gained access to the blood stream cannot be determined. He has thoroughly reviewed and brought up to date the literature of this rare disease, and adds one case of his own, in which the causative organism was Type XII pneumococcus. Purulent exudate, aspirated five days after adequate sulfadiazine therapy, again yielded this type of organism in pure culture. The incidence of pneumococcic arthritis as a complication of pneumonia is given as 0.3 per cent. Seventy to 75 per cent. of the cases of pneumococcic arthritis occur in association with pneumonia.

The usual clinical features of an acute pyogenic arthritis are seen in this disease, and the following are regarded as almost pathognomonic: white, periarticular oedema, with prominent venous collateral circulation; elevated temperature with the patient in good general condition; the absence of regional lymphadenopathy; and the rapidity of reappearance of swelling of the joint after aspiration. The disease is monarticular in about 75 per cent. of the cases.

Recommended treatment is similar to that for the usual pyogenic arthritides, but the observation made in 1902 by Herrick should be noted: "It is well to remember that, with serous and in a few cases even with purulent exudate, recovery has ensued either spontaneously or by the simpler measures of rest, compression, or aspiration".

The mortality rate is determined by the bacteraemia. In almost every joint infected by pneumococci, there will be some permanent damage. Evidence is lacking to establish a grave prognosis or high mortality for pneumococcic arthritis by itself.—*H. H. Beckering, M.D., Dallas, Texas.*

Causalgia. A Preliminary Report of Nine Cases Successfully Treated by Surgical and Chemical Interruption of the Sympathetic Pathways. I. Joshua Speigel and Jack L. Milowsky. *The Journal of the American Medical Association,* CXXVII, 9, January 6, 1945.

The more important literature on the subject is reviewed, and the following etiological factors are mentioned: neuritis ascending from the point of injury; abnormal vasomotor reflexes; irritation of the peripheral sympathetic plexus; stimulation of a hitherto unrecognized set of "nocifensor nerves"; some anatomical or biological peculiarity of certain afferent neuronic systems; and "an expression of sensory hypertonicity". The authors agree with others that "all that emerges from these theories as reasonably certain is that abnormal vasomotor activity usually accompanies the pain". The therapy of causalgia is aimed at one of three expedients: removal of the cause of irritation to the nerve; interruption of the afferent pathway in the peripheral nerve; and interruption of the sympathetic supply of the extremity.

Removal of irritation to the nerve is accomplished by neurolysis, by removal of adjacent foreign bodies, or by the injection of "trigger points" with procaine hydrochloride. Interruption of the afferent pathway has been performed in several ways: by resection and resuture of the nerve; by section of the painful nerve, rhizotomy, or even chordotomy; and by injection of the nerve with 60 per cent. alcohol. Interruption of the sympathetic supply of the extremity has been done by periarterial sympathectomy, which is being supplanted in this country by direct surgical and chemical attack on the ganglionated sympathetic chain; and by preganglionic sympathectomy. A real disadvantage of postganglionic sympathectomy is the increased sensitization to circulating epinephrine and sympathin. A review of preganglionic sympathectomy is given, and the authors then present their nine successful cases.

On the basis of their experience, the following conclusions have been drawn: (1) the syndrome followed injury to all or any of the major nerves of the upper extremity; (2) injury to a blood vessel frequently accompanies nerve injuries in causalgia, but is not a necessary accompaniment; (3) the most constant symptom of causalgia is hot burning pain aggravated by movement and friction; (4) the most common findings are a shiny, cold, profusely perspiring and frequently cracked skin in the involved extremity, with hyperaesthesia occurring in most of the cases; (5) roentgenographic evidence of decalcification of the involved extremity is frequently seen; (6) the pain does not appear to be due to the constant irritation of a scar or of a foreign body; (7) the degree and quality of pain are in no way commensurate with the type and extent of the injury; (8) the sensory deficit does not delineate the area of pain, but the two frequently shade into each other; (9) personality disorders and hysteria are the result rather than the cause of causalgia.

Their conclusions as to therapy are: (1) neurolysis is not a useful procedure in the treatment of

causalgia *per se*, although it may be necessary in the treatment of the specific nerve deficit; (2) it is injudicious to subject the patient to a series of operations ranging through neurolysis, nerve section, and periarterial sympathectomy before attempting chemical and surgical interruption of the sympathetic pathways; (3) interruption of the sympathetic pathway, temporarily by sympathetic block, or permanently by surgical sympathectomy, is a highly dependable form of treatment for causalgia; (4) a series of diagnostic sympathetic blocks should be performed to prove the efficacy of interruption of the sympathetic pathway before performing sympathectomy; and (5) occasionally the pain of causalgia can be more or less permanently controlled by sympathetic block with local anaesthesia where sympathectomy is not feasible.—*Brandon Carrell, M.D., Dallas, Texas.*

Pellegrini-Stieda Disease in the Bantu. P. Keen. *Clinical Proceedings. The Journal of the Cape Town Post-Graduate Medical Association,* III, 331, 1944.

In a group of 280 cases of injuries to the knee and chronic knee-joint conditions seen at the Non-European Hospital, Johannesburg, Pellegrini-Stieda disease was found seventeen times over a period of seventeen months.

The author states that, in the Bantu, the tibial collateral ligament is a larger structure (4.75 inches in average length, with extremes of 4.3 and 4.9 inches), whose insertion into the condyle of the femur is closely associated with that of the tendon of the adductor magnus. This anatomical difference is given as a reason for the spread of ossification beyond the ligament, and also for the conspicuous absence of lesions of the internal semilunar cartilage in the Bantu.

The average age in this group was 33.5 years. There were fifteen males, and two females. Definite trauma was noted in fourteen cases. In nine patients, the complaint was pain and stiffness; in seven, pain; and in one, pain and swelling. Ten of the seventeen cases gave roentgenographic evidence of osteo-arthritis, and two had clinical signs of it. The lesion of the tibial collateral ligament, however, overshadowed the evidences of osteo-arthritis where it was also present.

Excision of the ossified mass was indicated in some cases, but it could not be done because of the reluctance of the Bantu to undergo operative treatment. Immobilization with plaster-of-Paris was used, with absorption of the ossification in some. Massage, movements, and radiant heat helped to increase absorption.

Since closing the series, three other Bantu with Pellegrini-Stieda disease have been noted, making a total of twenty cases in about one and one-half years.

The Treatment of Gunshot Injuries of the Hip Joint in Forward Evacuation Areas. M. A. Traitel. *Khirurgiya,* No. 4, 52, 1944.

The writer's experience covers a large number of hip-joint wounds and permits the following conclusions: (1) early radical surgical interference with excision of the joint is the operation of choice as a life-saving measure, and also as providing the most satisfactory functional result; (2) conservative treatment should be a rare exception and may only mean delay, which may prove to be fatal; (3) wounds involving contiguous areas, such as the pelvis, greater trochanter, intertrochanteric areas, and the surrounding soft tissues must also be subjected to early radical surgical interference.—*E. Kaplan, M.D., New York, N. Y.*

Paget's Disease: Its Pathologic Physiology and the Importance of This in the Complications Arising from Fracture and Immobilization. Edward C. Reifenstein, Jr., and Fuller Albright. *The New England Journal of Medicine,* CCXXXI, 343, 1944.

In the light of two carefully studied cases, this paper discusses the serious implications of acute atrophy of bone, as a complication of Paget's disease following fracture and immobilization. The paper should be read in full, since it also covers briefly normal bone metabolism, the metabolic abnormalities osteoporosis, as opposed to those in osteomalacia and osteitis fibrosa generalisata, the morbid anatomy Paget's disease, and, finally, a concept concerning the pathological physiology in Paget's disease.

The bone lesions found in Paget's disease are not generalized, but they are spotty, and this argues gainst an endocrinological or metabolic basis. The initial lesion is bone destruction, and its cause is ntirely obscure. Destruction makes the involved bones less resistant to stress, and this leads to stimulaon of the osteoblasts and overproduction of bone. However, the repair is not completed, because the ocalized initial disorder persists, and alternating destruction and repair produce the pathognomonic nding of the so-called "mosaic structure". This appearance is created by the irregular cement lines, ach of which marks the point where destruction temporarily stopped and repair began. While the hanges in Paget's disease are similar to those in osteitis fibrosa generalisata of hyperparathyroidism, ere is one important difference. In the latter, bone is destroyed which can best be spared; while in aget's disease destruction occurs without regard to structure.

A distinct train of events follows immobilization of a bone containing Paget's disease. The lack of tress, probably aided by the alarm reaction of Selye, reduces the activity of the osteoblasts, and the vel of the serum phosphatase drops; but, because of the persistence of the initial bone-destroying

disturbance, there is an imbalance between bone destruction and bone formation. The increase of calcium and phosphorus coming from the bone leads to an increase in the urinary calcium and phosphorus. If the excretory capacity of the kidney is inadequate, hypercalcaemia results, and, unless this is overcome, "chemical death" may follow. Measures to overcome the hypercalcaemia are: an increase of fluid intake, a reduction in calcium intake, and as brief a period of immobilization as possible. Although the broken bone as a whole becomes decalcified, a calcifying callus promptly occurs at the fracture site. This supposedly is due to some local influence excited by the fracture, which stimulates the osteoblasts.—*Paul P. Swett, M.D., Bloomfield, Connecticut.*

ORTHOPEDIC ASPECTS OF BRUCELLOSIS. E. G. Chuinard. *Northwest Medicine,* XLIII, 279, 1944.

There is not infrequently some confusion in the symptomatology and diagnosis of brucellosis and certain orthopaedic conditions. Aside from brucellosis spondylitis, this infection frequently localizes in tendinous insertions, especially in the supraspinatus, the glutei, the coccygeus, the levator ani, and the piriformis muscles. The main symptoms are weakness, fatigue, and soreness at the tendinous insertions, together with pains through the neck and head. The signs are tenderness at the tendinous insertions, and tenderness and weakness of the muscle. The fever signs are of less importance. The orthopaedic surgeon and the internist must work in close cooperation on these cases.—*Charles Lyle Hawk, M.D., Los Angeles, California.*

SOME JOINT AND FRACTURE PROBLEMS OF THE ACCIDENT COMMISSION. Wilmer C. Smith. *Northwest Medicine,* XLIII, 360, 1944.

The author stresses the danger of permanent stiffness of the shoulder joint in injuries sustained after the fifth decade. It is imperative, therefore, that in immobilization of the shoulder joint, the humerus should be placed in a horizontal position, with the forearm fixed at right angles,—that is, pointing straight upward. This will permit maximum abduction as an end result. The author severely condemns unnecessary open reductions of fractures, and makes careful distinctions between delayed union and non-union. Prolonged and adequate immobilization in cases of delayed union will nearly always prevent non-union.—*Charles Lyle Hawk, M.D., Los Angeles, California.*

MYELOGRAPHY WITH PANTOPAQUE AND A NEW TECHNIC FOR ITS REMOVAL. Wendell G. Scott and Leonard T. Furlow. *Radiology,* XLIII, 241, 1944.

Neither air, lipiodol, nor thorotrast is an entirely satisfactory contrast medium for myelography. In search for a better one, Warren, Strain, Plati, and their associates developed ethyl iodophenylundecylate, a mixture of isomers obtained by the addition of iodobenzene to ethyl undecylate in the presence of aluminum chloride, and containing 30.5 per cent. of iodine in firm organic combination. It is called pantopaque, and is considered to be inert, there having been no reports, thus far, of meningeal irritation. Less viscid and lighter than lipiodol, but heavier than spinal fluid, it is more easily aspirated from the spinal canal. In the authors' experience, it is satisfactory for spinal myelography. The details of introduction and of examination are given. In the removal of pantopaque by the authors' method, no effort is made to aspirate by suction "since in so doing the nerve roots are frequently pulled against the needle and cause pain as well as block the exit of the oil". The needle, introduced squarely in the mid-line, is left in place during the examination and during the removal of the pantopaque.

For removal, the craniad portion of the column of oil is flowed beneath the tip of the needle, the stilette is removed, and spinal fluid bubbles out of the needle. The patient is then told to take a deep breath, and then bear down as though attempting to move his bowels. This is Valsalva's well-known experiment of forced expiration against a closed glottis, and has the effect of increasing intraspinal pressure. During this manoeuvre, the whole column of opaque oil moves craniad from 0.5 centimeter to as much as five to eight centimeters, and it becomes narrowed. These changes result from engorgement of the venous plexuses surrounding the dura. The thinner spinal fluid is displaced, leaving the oil in more intimate contact with the tip of the needle. The Valsalva manoeuvre is repeated until all the oil is removed,—usually within twenty minutes—the table being readjusted to keep the oil beneath the needle tip. All but a few drops of oil can be removed in this way.

The advantages of pantopaque over other contrast media are: increased fluidity, leading to more easy removal; lack of irritation; and absorbability, usually three cubic centimeters within a year.

Myelography is probably necessary only in those cases in which clinical signs of disc protrusion are not unequivocal, and in the identification of multiple protruded discs.—*Edward N. Reed, M.D., Santa Monica, California.*

OSTEOPOROSIS CIRCUMSCRIPTA CRANII: ITS PATHOGENESIS AND OCCURRENCE IN LEONTIASIS OSSEA AND IN HYPERPARATHYROIDISM. Frank Windholz. *Radiology,* XLIV, 14, January 1945.

Osteoporosis circumscripta cranii was first described by Schüller as large, irregular, circumscribed areas of osteoporosis in the cranium. Sosman demonstrated a histological relationship between osteoporosis circumscripta and Paget's disease. For a time this evidence seemed to be corroborated, and the lesions were thought to be an atypical form of Paget's disease, "probably the absorptive or destructive

phase with the productive phase held in abeyance". Schmorl first noted both gross and microscopic changes, which he considered to be a result of circulatory disturbances; they resembled hemorrhagic infarcts, rather than the anatomical changes found in Paget's disease. A third histological picture was noted by Schellenberg, one which resembled osteitis fibrosa

Of the published cases of osteoporosis circumscripta, 60 per cent. have been associated with Paget's disease, and 20 per cent with leontiasis ossea, or bony tumors of the maxilla. In a case in which osteoporosis was associated with a condition believed to be leontiasis ossea, the latter was variously interpreted as leontiasis ossea, Paget's disease, osteitis fibrosa, osteofibroma, and osteoma Recently, the author observed a case of osteoporosis circumscripta with histologically verified leontiasis ossea (Virchow type).

Three cases are presented, two of leontiasis ossea, and one of hyperparathyroidism. One case was that of the Virchow type of leontiasis ossea The histological picture was studied from a gum biopsy. This revealed "Complete transformation of the bone tissue with hyperplasia due to osteoblast activity and simple metaplasia; fibrous bone marrow containing inflammatory cells and capillary blood vessels; bone resorption by osteoclasts with formation of small cavities" No hyperplasia or hyperostoses were seen in the vault It was felt that the vault changes (osteoporosis) were secondary to the leontiasis ossea, but not intimately and topically connected with it

Pathologically, two types of osteoporosis are known; one represents circulatory disturbances, with hemorrhagic changes and decalcification, and the other, Paget's disease. The hemorrhagic form may be considered a primitive non-specific reaction common to many diseases of the cranium, and one which may be followed by the characteristic mosaic structure and fibrous bone marrow of Paget's disease.

The second case described was one of fibrous osteodystrophy which clinically resembled leontiasis ossea There were extensive hyperostoses of the cranium, surrounded by wide areas of osteoporosis, giving the impression that the osteoporosis was a change largely involving the vault

The third case was one of hyperparathyroidism, proved by the removal of a parathyroid adenoma, which weighed seven grams The localization and outline of the osteoporotic areas closely followed those of Paget's disease They developed five years after the first cranial changes thus suggesting a circulatory disturbance

The pathogenesis of these lesions lies in circulatory disturbances caused by space-occupying lesions near the base of the skull or in the facial bones Serial microscopy of biopsy specimens revealed obliterated blood vessels running into areas of quiescent bone tissue with no cellular reaction about the lamellae Areas of primitive osteoporosis may undergo structural transformation corresponding to the demands of the statics of the vault

Osteoporosis circumscripta cannot be regarded as a type or phase of Paget's disease or of any other disease entity It occurs most often in Paget's disease, however, and frequently may be transformed into it The "primitive" form of osteoporosis circumscripta is a characteristic reaction of the bones of the cranium, and is probably caused by circulatory disturbances in the presence of bony hyperplasias or of bony tumors near the base of the skull—*William H Wright, M D, Santa Monica, California.*

La artritis deformante de las extremidades inferiores (Degenerative Arthritis in the Lower Extremities). R. Arguelles. *Revista Española de Cirugía, Traumatología y Ortopedia*, I, 97, 1944.

Arguelles reviews the progress which has been made in the study of degenerative arthritis in the lower extremity. Degenerative arthritis does not occur in articulations with normal form and function. It is also important to have the joint habitually used midway between the extremes of motion. In the hip, congenital abnormalities of the hip joint are among the chief causes of degenerative arthritis, congenital subluxation, as Calot has shown, leads to degenerative arthritis in later life. In the knee, genu varum or genu valgum, often insignificant in amount, leads to the formation of degenerative arthritis The deformities mentioned by Jansen, "genu impressum" or "patella alta", may act as causative factors. The disease is often associated with flat feet, the bones of the foot under the weight-thrust go into internal rotation, then degenerative arthritis sets in in the mid-tarsal and astragaloscaphoid joints

In treatment the author advises correction of static alterations A brace can be used for genu varum or genu valgum The hip can often be treated surgically. Osteotomy after the manner of McMurray is the usual procedure. If very severe pain is present, ankylosis is advised, but this can be used only in unilatera cases Arthroplasty represents an ideal procedure in bilateral cases, but does not always relieve pain—*John G Kuhns, M.D, Boston, Massachusetts*

Tumeurs malignes du squelette histiocyto-sarcome et tumeur d'Ewing (Malignant Tumors of the Skeleton Histiocyto-Sarcoma and Ewing's Tumor) P. Lombard and J Montpellier *Revue d'Orthopédie et de Chirurgie de l'appareil Moteur*, XXVI 717, 1939

The authors report a case of bone tumor, which they believe had not been identified at the time of their description They also report a case of Ewing's tumor by way of comparison

The interpretation of this new type is somewhat difficult It resembles the neoplasm recently described by Laffargue as "histiocyto-sarcoma" of the skin of the breast The authors believe that the tumor

is a reticulosarcoma of the bone marrow with a simultaneous fibrocytic and histiocytic giant-cell evolution.

They give the following classification of reticulo-sarcomata:

1. Undifferentiated (Ewing's tumor);
2. Partly differentiated;
3. Differentiated: a. Reticulocytic; b. Reticulo-endothelial;
4. Progressing: a. Fibrocytic; b. Histiocytic; c. Lymphoblastic; d. Myeloblastic; e. Erythroblastic; f. Plasmocytic;
5. Metaplastic sarco-endothelial;
6. Complex (mixed) or intermediary.

The report is of unusual interest. —*E. Kaplan, M.D., New York, N. Y.*

THE DUAL PLATE, NO CAST, INTERNAL FIXATION OF SHAFT FRACTURES. Louis W. Breck and W. Compere Basom. *Southern Medical Journal*, XXXVII, 582, 1944.

In the dual-plate method, employed by the authors, one set of screws or bolts is used to fix two plates across the site of the fracture. No cast is necessary, as this method secures rigid fixation. It is especially useful in the lower third of the tibia, where non-union frequently occurs. A special jig is used to be sure the screws go in at right angles. One case of a simple, oblique fracture at the junction of the lower and middle thirds of the right tibia and fibula is reported and is illustrated. Six weeks after fixation, roentgenograms showed beginning union, and full weight-bearing was started. Three months later, good union was demonstrated.—*Fred G. Hodgson, M.D., Atlanta, Georgia.*

ISTHMUS DEFECTS OF THE FIFTH LUMBAR VERTEBRA. R. Beverly Raney. *Southern Medical Journal*, XXXVIII, 166, March 1945.

An isthmus defect of the fifth lumbar vertebra may be unilateral or bilateral. This defect is a significant factor in the cause of backache. It is not uncommon, as shown by roentgenograms and examination of skeletons. It is found in about 5 per cent. of skeletons examined, from different countries and in various races. In a series of 300 patients complaining of low-back pain, with or without sciatica, it was discovered in ninety-four, or 31 per cent.; in sixty-three the defect was bilateral.

The gross appearance of the tissue within the defect is that of fibrous tissue. Microscopic examination shows fibrous tissue and a gradual transition between it and the bone on either side of the defect. The spinous process is hypermobile, especially in bilateral cases. The cause is supposed to be congenital, or possibly a fracture sustained at birth. The chief complaints are low-back pain, weakness, and stiffness. Pain is increased by mechanical stress. Involvement of nerves of the lower extremities may be evidenced by radiating pains, usually sciatic in distribution, accompanied at times by areas of numbness and tingling. Muscle spasm and tenderness of the low back may be present. If the nerves to the lower extremities are affected, physical signs may include decreased reflex responses, and even muscle weakness. Roentgenographic examination is most important, especially oblique projections.

Treatment in most cases should be conservative, with a firm mattress and a fracture board at night. A plaster body jacket or a strong, well-fitted corset is advised for ambulatory use; heat and massage for relief of pain, together with graded exercises to improve posture and muscle strength. Removal of foci of infection, and administration of large doses of vitamins help in some cases. Spine fusion is recommended for patients not relieved by conservative measures.—*Fred G. Hodgson, M.D., Atlanta, Georgia.*

TRAUMATIC OSTEOCHONDRITIS OF THE PATELLA. Francis J. Cox. *Surgery*, XVII, 93, January 1945.

The author states that diffuse osteochondritis of the patella can result from trauma, and he reports six such cases. Following trauma, the acute symptoms subside, and for weeks or months the knee is apparently normal; then appears a low-grade chronic effusion with pain and discomfort, and locking or snapping. The average duration of symptoms in these cases was 13.2 months. The author performed a patellectomy, and found softening and fissures of the patella with a yellowish articular cartilage. There were thickening, hyperaemia, and villous degeneration of the synovial membrane, usually confined to the suprapatellar pouch. Increased fluid was found, as well as pannus formation at the edges of the articular cartilage of the patella and the femoral condyles.

The patellectomy performed on these six patients entirely relieved and alleviated the symptoms, and resulted in the disappearance of the inflammatory changes of the synovial membrane.—*Lee M. Cattell, M.D., Chicago, Illinois.*

TREATMENT OF TENDONS IN FINGER AMPUTATIONS AND DESCRIPTION OF A NEW INSTRUMENT. George V. Webster. *Surgery*, XVII, 102, January 1945.

Commander Webster discusses the attachment of the tendons of the finger and the treatment of tendons in amputations. He states: "Flexor tendons need not be sutured to bone or tendon sheath in clean cases, and must not be overlapped and sutured over the end of the bone to the extensor ten-

dons". It is better to allow the tendons to retract within the sheath. The author recommends that, if the wound is contaminated, the tendons be anchored at the point of amputation, and the tendon sheath be left open to avoid spread of the infection. Such tendons often become adherent and cause loss of function. In such cases, they should be excised. A tendon stripper, suitable for freeing such tendons, is described.—*Lee M. Cattell, M.D., Chicago, Illinois.*

The Conservative and Operative Treatment of Lesions of the Intervertebral Discs in the Low Back. J. Albert Key. *Surgery,* XVII, 291, February 1945.

Dr. Key believes that more and more of the symptoms, previously attributed to sacro-iliac or lumbosacral strains, arthritis, subluxation, the lumbosacral facet syndrome, or postural strains of the low back, are really due to lesions of the intervertebral discs in this area. The author divides patients with low-back pain into three groups:

1. *Ambulatory patients* are treated by support to the low back, manipulation, stretching, and correction of the body mechanics by exercise, a hard bed, vitamin B, weight correction, salicylates, and a change of occupation if necessary.

2. *Bed patients* are those whose symptoms are so severe that they are not able to carry on their daily routine. Many of these people must now be treated at home, rather than in a hospital. The author recommends bed rest on a rigid bed with flexion of the lumbar spine, local heat, hot tubs, and exercises, with medication for pain as necessary. Occasionally manipulation under anaesthesia may be used.

3. *Surgical patients* are those patients for whom an adequate program of conservative treatment has been tried and proved unsuccessful. For such patients surgical removal of the herniated nucleus, with or without spine fusion, is recommended. The author describes the operative technique in detail. In 120 consecutive operations for ruptured intervertebral discs, the author reports only one fatal case.—*Lee M. Cattell, M.D., Chicago, Illinois.*

Vascular Insufficiency of the Lower Extremity Due to Osteoma of the Femur. Robert M. Rankin. *Surgery,* XVII, 419, March 1945.

The author reports a case of a white male, forty-eight years of age, who complained of progressively severe intermittent claudication. This was relieved by the removal of an osteoma of the femur, which had been compressing the femoral artery and vein for at least four years. There was secondary arteriosclerosis present at the site of the compression. Symptomatic relief following surgery was dramatic, despite the failure of the arterial pulsations in the foot to return to normal.—*Lee M. Cattell, M.D., Chicago, Illinois.*

Bone Regeneration Following Osteomyelitis. Laurence H. Mayers. *Surgery,* XVII, 463, March 1945.

The author reports a human bite of the left middle finger in a male, forty years of age, which caused osteomyelitis. Pyogenic organisms, spirilla, and anaerobes were all cultured from the wound as the case progressed. By frequent roentgenograms the progress of the destruction and the regeneration of bone was carefully followed. Treatment covered the conventional range and was all directed toward giving the phagocytic type of cell a chance to work to the maximum advantage. The finger was reopened five weeks after the initial wound, and a small amount of necrotic tissue was found. It was five and a quarter months before there was roentgenographic evidence that the bone atrophy had disappeared, and the cortex was commencing to reappear. This patient has a usable finger, although the terminal joint is partially ankylosed.—*Lee M. Cattell, M.D., Chicago, Illinois.*

A Newer Method in the Treatment of Fractures of the Os Calcis. Ben L. Schoolfield. *Texas State Journal of Medicine,* XL, 294, 1944.

A method for internal fixation of fragments and for reduction of lateral displacement in fractures of the body of the calcaneus is described.

A vise, adequately padded, is applied and screwed up firmly over the sides of the displaced fragments just below the tips of the malleoli. The lateral displacement is reduced and checked roentgenographically. A Steinmann pin is then introduced through the middle of the posterior surface of the heel. It is directed obliquely forward and upward. Any upward tilting of the posterior fragment is corrected by depressing the drill and pin, after which the pin is driven into the anterior fragment for fixation. The vise is then removed, and a padded plaster-of-Paris dressing is applied to the limb, from the toes to just below the knee. During application of the plaster, the posterior part of the heel is depressed to maintain alignment, the forefoot is depressed in countertraction, while the foot is fixed at a right angle to the leg with a mild varus tilt.

After six weeks the cast is removed. If union of the fragments appears to be progressing, the Steinmann pin is taken out; otherwise it is left in and the plaster is re-applied. Union is determined by roentgenogram.

Some swelling of the foot and ankle, with localized tenderness, may be expected. Weight-bearing is allowed when solid union has taken place.

The author has treated several cases of fracture of the body of the calcaneus in the past two years, with satisfactory results in all.

In some cases where the fracture line has penetrated the subtalar joint, traumatic arthritis has been observed, the result of improper reduction and fixation. Such an end result is unlikely, if restoration of the joint surfaces has been carried out along anatomical lines

FRACTURES OF TRANSVERSE PROCESSES OF LUMBAR VERTEBRAE. Jesse T. Nicholson and John H. Allan. *United States Naval Medical Bulletin*, XLII, 780, 1944.

The authors cite nineteen cases of fractures of the transverse processes of the lumbar vertebrae treated aboard a hospital ship by local injections of procaine, and early mobilizing exercises. They consider the local contusion and tearing of muscle structure the important pathology. The quadratus lumborum originates from the crest of the ilium, and is inserted into all five lumbar transverse processes and into the twelfth rib. The iliopsoas also arises from all five vertebrae, and is inserted into the lesser trochanter of the femur. All previous treatment has included prolonged rest in bed, plaster jackets, braces, and inactivity, work being out of the question for three to six months. The authors stress the importance of getting men back to active duty on board ship.

In the authors' cases, the transverse processes most frequently injured were those of the second, third, and fourth lumbar vertebrae. Treatment consisted of thorough infiltration of the soft tissues around the affected area with ten cubic centimeters of a 1 per cent. solution of procaine. This was done every three days for four doses. Immediately following these injections, the patient performed exercises, such as (1) raising his back and shoulders up from the prone position, (2) rotating his shoulders first to the right and then to the left, while in a sitting position, (3) lateral bending, (4) touching the deck with his fingers from a standing position. Each of the exercises was done fifteen times, and was repeated twice daily.

The authors base their good results on Leriche's theory that procaine (1) eliminates the reflex arc of pain, (2) activates early mobilization, and (3) interrupts vasomotor phenomena. They claim that active motion eliminates the scar which is brought about by exudate around the nerves and muscles.—*A. J. Langan, M.D., Iowa City, Iowa.*

GRAMICIDIN S AND ITS USE IN THE TREATMENT OF INFECTED WOUNDS. G. F. Gause and M. G. Brazhnikova. *War Medicine*, VI, 180, 1944.

Gramicidin is one of the newer and as yet little used agents in the treatment of infections. The technical name for this substance, tyrothricin, is gradually becoming more widely accepted. The substance is extracted from the bacteria of certain soils. Apparently there are several different variations including gramicidin prepared by Gause and Brazhnikova, tyrothricin, gramicidin of Dubos, and tirocidine hydrochloride. Gramacidin S, described in this article, was found to be highly bactericidal for staphylococci, streptococci, pneumococci, and the more common gas-producing bacilli.

The substance is as toxic as tyrothricin. It is used in the same way for local application to infected wounds.—*Edward L. Compere, M.D., Chicago, Illinois.*

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The Editor

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The Journal of Bone and Joint Surgery

SURGICAL OBLITERATION OF BONE CAVITIES FOLLOWING TRAUMATIC OSTEOMYELITIS

BY LIEUTENANT COLONEL MARVIN P. KNIGHT AND MAJOR GEORGE O. WOOD
Medical Corps, Army of the United States
From the Orthopaedic Section, Crile General Hospital, Cleveland, Ohio

One of the most serious reconstruction problems in War casualties is the treatment of bone cavities associated with loss of skin and soft tissue, following infected compound fractures. Especially has difficulty been encountered in the handling of large bone defects in the tibia and the femur in the vicinity of the knee.

The destructive nature of war missiles results in severe loss of bone substance, followed by a varying degree of infection and dense scar formation. The bone cavity is reluctant to heal, and the tissue is subject to necrosis and recurrent inflammation. Furthermore, the bone is usually so weakened that full function cannot be resumed; and, even if union occurs, refracture is imminent unless the bone is reinforced by a graft. Bone-grafting is contra-indicated in the presence of granulation or scar tissue, and is hazardous without adequate skin coverage. In spite of the usual methods of closed plaster treatment, sequestration, and chemotherapy, a large depressed cavity persists with thin adherent scar and incomplete union. Some patients have required a permanent brace, while others have been subjected to a collapsing operation, with resultant shortening or even amputation.

The authors have adopted a procedure which expedites healing, and obliterates these cavities in the long bones of the extremities.

The program consists of early and complete sequestrectomy, followed ordinarily in about seven days by the application of a split-thickness skin graft as a dressing, applied meticulously into the depths of the saucerized area.

This procedure effectively converts the infected wound into a closed fracture, so that the wound remains healed and dry. However, there still remains a defect in the bone, which seriously impairs its strength, particularly important in the weight-bearing requirements of the lower extremity. Bone does not regenerate beneath these adherent split-thickness grafts, and the defect remains essentially the same size, in spite of the natural tendency of the soft tissue to contract. In most instances, at the time of bone-grafting, it has been found necessary to replace a split-thickness skin graft with a full-thickness graft by some plastic method, in order to ensure the success of the procedure.

In the past, attempts have been made to obliterate septic bone cavities by the introduction of antiseptic paste, preparatory to a pedicle graft of fat or muscle. Pedicle skin

grafts also have been introduced, in an effort to secure an epithelial covering without any attempt at obliteration of the cavities. The result of these efforts has been variable and frequently unsuccessful. In the present series, therefore, these cavities have first been thoroughly cleansed, then lined with split-thickness skin, which was later removed. Finally the cavities were obliterated by the application of the bone graft and simultaneous covering with stable full-thickness skin. Experience with a limited number of cases indicates that even severe lesions of this character can be cured by a three-stage program of (1) thorough sequestrectomy and excision of the scar, (2) early split-skin grafting, and, finally, (3) bone-grafting followed by the immediate application of a full-thickness pedicle skin graft.

DETAILS OF THE STAGES OF THE PROCEDURE

The First Stage: Sequestrectomy and Preparation of the Cavity

This first stage is planned and carried out so that the resultant wound will be adaptable to the early application of a split-thickness skin graft, and so that the final scars will be advantageously placed. All non-viable bone and bone of questionable viability should be removed; and the fracture site should be saucerized, so that granulation tissue will cover the bone surfaces. An attempt is made to preserve any union which may be present, but occasionally minimal fibrous union must be sacrificed. For obvious reasons, all cicatricial soft tissue in the region of the fracture is excised as completely as possible, and, in the event that a joint is involved in the osteomyelitic process, the cartilage is similarly removed. The wound is packed open with vaseline gauze, and the affected extremity is provided with plaster immobilization, pending subsequent operative procedures.

After five to seven days, the wound is inspected, and its suitability for skin-grafting is determined. Usually it is healthy with a very thin layer of granulation tissue overlying the bone surfaces; but occasionally, in those cases in which suppuration has been allowed to continue over a period of time sufficient to produce extensive soft-tissue fibrosis and bone sclerosis, the outward growth of granulations over the eburnated bone surfaces will probably be slow. In these cases, grafting must be deferred until the bone is covered with the minute granulations necessary for a successful skin-grafting. With the gradual accumulation of experience, the saucerization stage can be improved so that this difficulty becomes minimal. The unusual period of time which has elapsed between stages in some cases in this series may be explained by the duration of the osteomyelitis before this method of treatment was instituted, the degree of osteosclerosis about the fracture site at the time of primary operation, and the lack of experience necessary to determine adequately the proper method of dealing with this type of reconstruction.

The Second Stage: Application of Split-Thickness Skin Graft

The use of the Padgett dermatome enables the operator to obtain without difficulty grafts of predetermined thickness, and to provide sufficient skin to cover the largest saucerized areas. This graft, preferably .010 to .016 of an inch thick, is obtained from the most convenient source, and its rubberized epithelial surface is lightly dusted with sterile powder to prevent adherence to the dressing. The recipient area is prepared by curettage of the granulating surface, with removal of any tissue which is oedematous or avascular. The graft is then applied to the saucerized area, and is fitted into the depressed, irregular bone cavity by shaping the thin sheet of split skin into an irregular blunt cone. The graft margins are sutured to skin edges, and a pressure dressing of machinist's waste is meticulously placed from the bottom of the cavity outward, so that all recesses are completely and snugly filled, to ensure intimate contact between the graft and the recipient area. The entire extremity is wrapped with an elastic bandage, and immobilization is carried

out by means of a splint or cast. Chemotherapy, consisting of penicillin with or without sulfonamides, is administered for two or three days postoperatively. The initial dressings are routinely removed at the end of six days, and a plain vaseline-gauze dressing is applied. At this dressing, it is customarily found that from 80 to 95 per cent. of the skin graft has taken, and, not infrequently, the entire surface is completely covered with epithelium. Subsequently the wound is treated in the same manner as any skin graft, while proper attention is paid to immobilization of the underlying fracture. Physiotherapy is instituted for treatment of joints and soft tissues, as soon as the degree of healing permits.

When the grafted surface has become completely epithelialized, and the graft is relatively stable, further surgery is indicated for the obliteration of the bone cavity.

The Third Stage: Obliteration of the Bone Cavity with Autogenous Bone Chips

The principal factors in the success of this stage are:

1. Planning of suitable full-thickness covering for the defect;
2. Complete excision of the split-thickness covering from the depth of the saucerized area;
3. Procurement of a sufficient amount of bone chips to fill the cavity;
4. Covering of the chip-filled cavity with skin and subcutaneous tissue, in such a manner that tension is avoided.

In planning the final skin covering for the defect, it is frequently possible to undercut the margins of the skin adjacent to the cavity, so that viable full-thickness skin may be closed over the cavity without tension. It has been found advisable, when possible, to plan the closure so that the suture line does not overlie the cavity, as it has been found that the incision apparently heals better when not placed directly over the recently filled cavity. Therefore, it is frequently necessary to elevate a double-pedicle sliding flap in the region adjacent to the cavity, and to shift the flap to relocate the suture line. These flaps may usually be shifted without delay, and their viability will usually be satisfactory, if the ratio of length to width does not exceed three to one. In most cases one flap is adequate, but occasionally it is necessary to raise flaps on both sides of the cavity. Rarely, after the flaps have been elevated, their circulation may not seem adequate, so that it becomes necessary to "delay" the procedure for two or three weeks and return the flaps to their original beds. Occasionally, when an extensive loss of surface covering has occurred, it may be necessary to migrate skin and subcutaneous tissue by the pedicle method from more distant sources. It is imperative, therefore, that skin flaps actually be prepared and tested over the defect, before any effort is made to excise the initial graft or to apply the bone chips.

With satisfactory full-thickness covering of the defect assured, it is safe to proceed with the excision of the split-thickness lining of the saucerized area. The medullary canal of both fragments is reopened, and the bone surfaces are scarified throughout. Autogenous bone chips are then procured from any convenient source in quantities sufficient to fill the cavity (the wing of the ilium provides an excellent source). These chips are transferred to the prepared cavity, and the flap or flaps are shifted over the bone-filled cavity. A split-thickness graft, obtained from the thigh, is utilized to cover the denuded area representing the former location of the pedicle flap. Pressure dressings of machinist's waste are again carefully applied, and held with elastic bandages. Chemotherapy is continued postoperatively for a period of three to five days, and the suture line and skin-flap covering of the graft are inspected on the sixth day.

As soon as the sutures have been removed, the extremity is immobilized according to the degree of bony union which exists.

A brief synopsis of cases treated by this method, in a series of patients wounded in combat, is summarized in Table I.

FIG. 1-A
Photograph prior to final-stage operation, showing split-thickness graft lining cavity.

FIG. 1-B
Photograph two weeks after final operation.

FIG. 2-A
Photograph prior to final-stage operation.

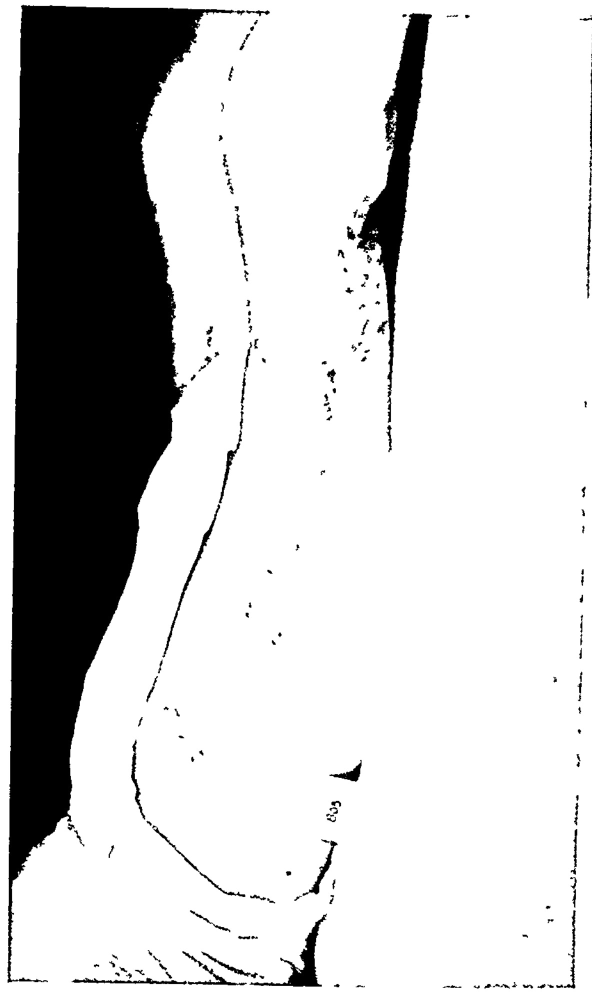

FIG. 2-B
Photograph showing final result Two months after operation

Fig 1-C

Fig 1-D

Fig 1-C Roentgenogram of bone cavity after saucerization, prior to final-stage operation

Fig 1-D Roentgenogram following insertion of chips from ilium and plastic repair.

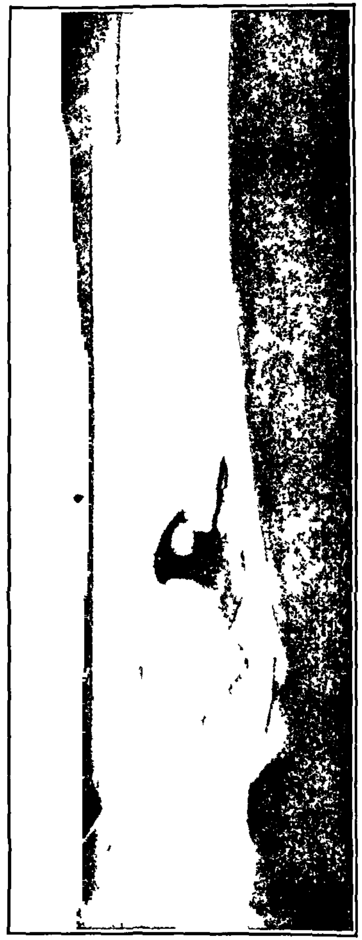

Fig 2-C

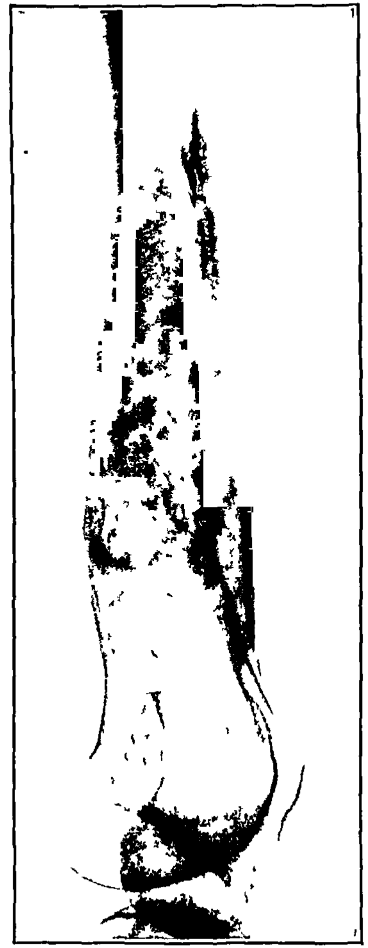

Fig 2-D

Fig 2-C Roentgenogram showing structural weakness prior to final-stage operation

Fig 2-D Postoperative roentgenogram of chip-filled cavity in femur, showing solid union, clinically firm

FIG. 3-A
Photograph prior to final-stage operation.

FIG. 4-A
Cavity lined with split-thickness skin.

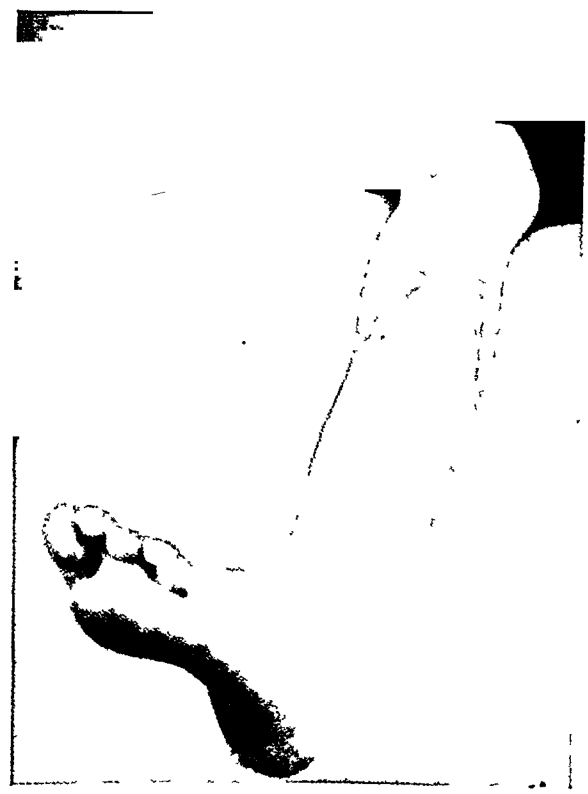

FIG. 3-B
End result, showing good skin coverage.

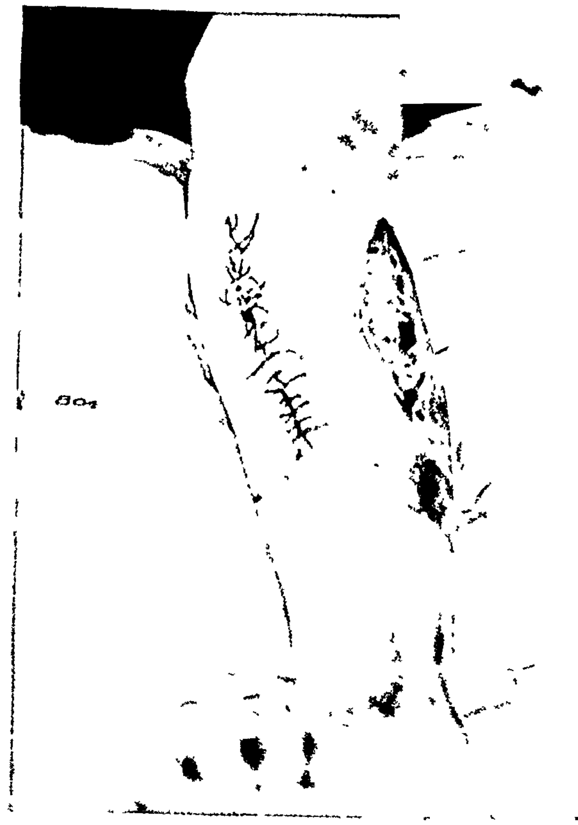

FIG. 4-B
Appearance at first dressing following final-stage operation.

FIG. 3-C

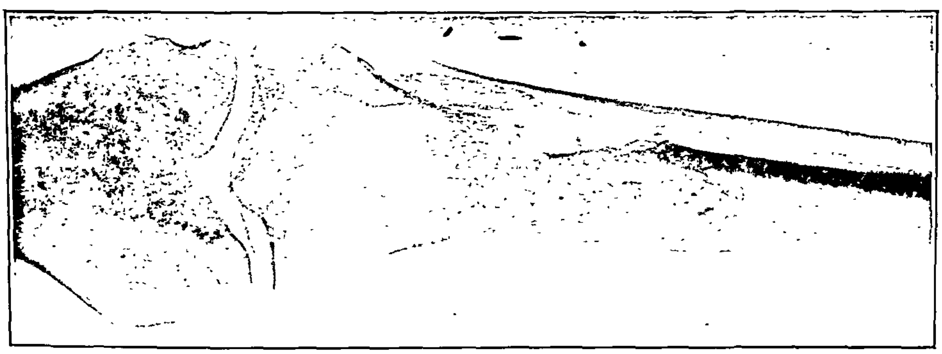

FIG. 3-D

Fig. 3-C: Roentgenogram showing skin-lined bone cavity (filled with barium sulfate to show the depth of the cavity).

Fig. 3-D: Roentgenogram showing cavity filled with bone chips from the ilium.

FIG. 4-C

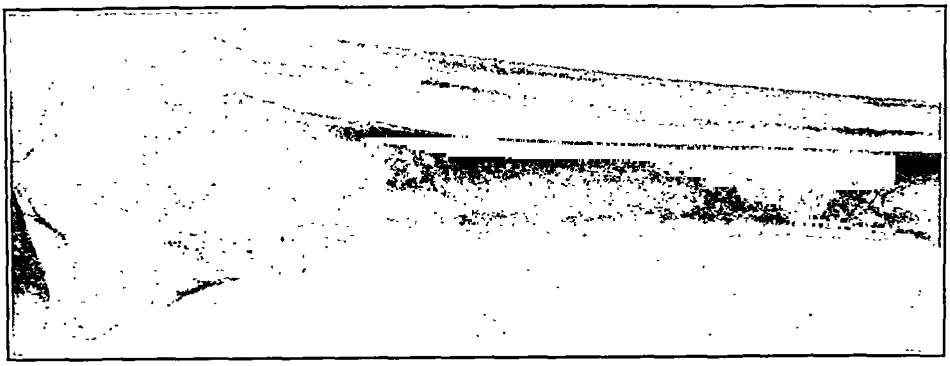

FIG. 4-D

Fig. 4-C: Roentgenogram before reconstruction with bone chips.

Fig. 4-D: Roentgenogram after reconstruction with bone chips.

Fig. 5-A

Photograph showing fracture site prior to final-stage operation.

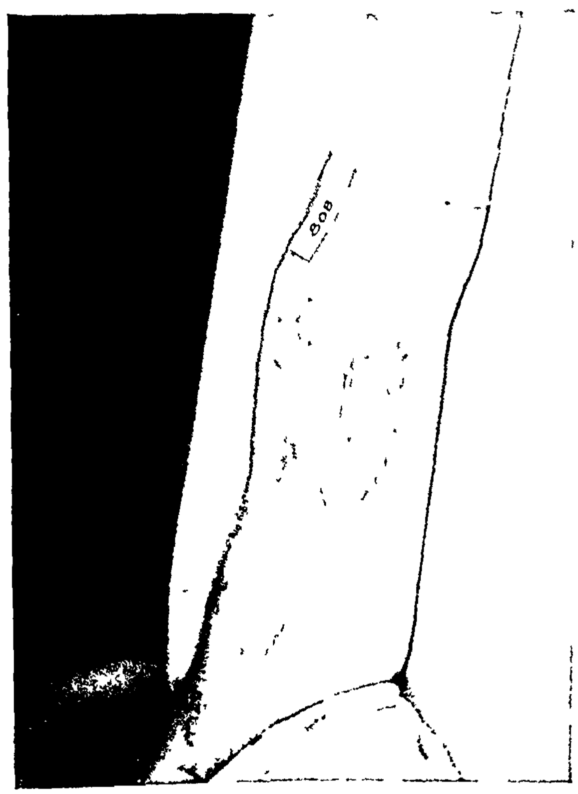

Fig. 5-B

Photograph showing result two months after final operation.

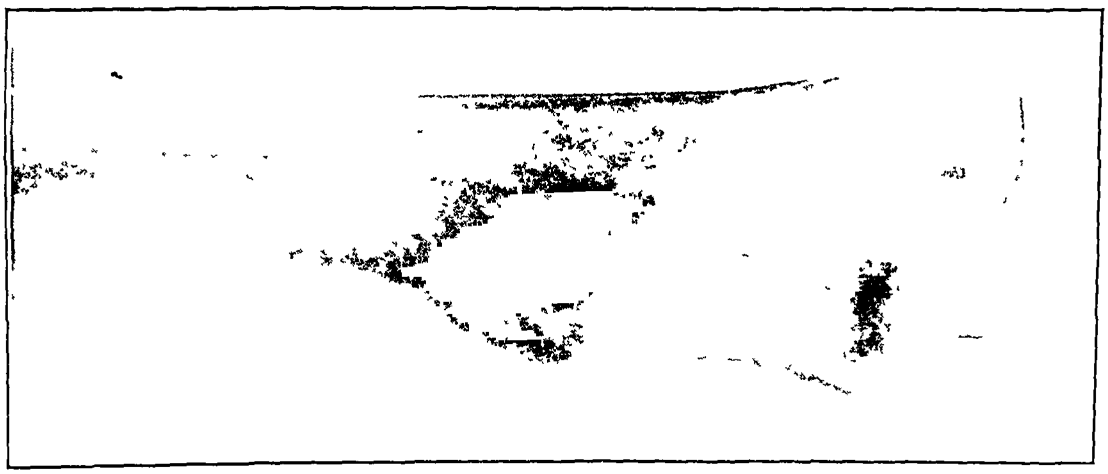

Fig. 5-C

Fig. 5-D

Fig. 5-C: Roentgenogram showing depth of the cavity (filled with barium sulfate).

Fig. 5-D: Roentgenogram showing cavity filled with chips.

Fig. 6-A

Fig. 6-B

Fig. 6-A: Roentgenogram showing proximity of cavity to knee joint.
Fig. 6-B: Roentgenogram showing preservation of joint following insertion of chips.

Fig. 7-A

Fig. 7-B

Fig. 7-A: Recent case, showing deep wound from shrapnel.
Fig. 7-B: Showing rapid healing after insertion of bone chips.

TABLE I

SUMMARY OF CASES

Case Number	Age	Involved Bone	Intervals: Injury to initial step	Intervals: Sequestrectomy to S.T. graft	Intervals: Graft to final operation	Obliteration of Bony Defects by Bone	Soft-Part Healing	Complications
			Months	*Days*	*Weeks*			
1.	23	Tibia	2	17	12	Complete	Complete	Hematoma (evacuated).
2.	28	Tibia	2	19	14	Complete	Complete	None
3.	25	Tibia	1.5	37	7	Complete	Complete	Hematoma (aspirated).
4.	29	Femur	5	44	9	Complete	Complete	None
5.	25	Tibia	1.5	11	8	Complete	Complete	None
6.	20	Tibia	4.5	14	15	Complete	Complete	None
7.	24	Tibia	1.5	36	12	Complete	Complete	None
8.	23	Tibia	6	14	8	Complete	Complete	None
9.	29	Tibia	5.5	29	10	Complete	Complete	None
10.	19	Femur	5	18	9	Complete	Complete	None
11.	25	Femur	4.5	19	8	Complete	Complete	None
12.	21	Tibia	6	12	6	Complete	Complete	None
13.	23	Femur	6.5	10	7	Complete	Complete	None
14.	27	Tibia	4	8	9	Incomplete	Incomplete	Suppuration present (bone chips viable).
15.	22	Tibia	3.5	7	5	Complete	Complete	None
16.	28	Tibia	3	8	8	Complete	Complete	None
17.	30	Tibia	2.5	9	7	Complete	Complete	None
18.	23	Femur	3	10	8	Incomplete	Incomplete	Draining sinus near operative site.
19.	25	Femur	4.5	7	8	Complete	Complete	None
20.	21	Tibia	2	8	5	Complete	Complete	None
21.	26	Tibia	3.5	9	7	Complete	Complete	None
22.	27	Tibia	3	10	6	Complete	Complete	None
23.	21	Tibia	2.5	7	9	Complete	Complete	None
Average	24	Tibia 17 Femur 6	3.5	16	8.5			

SUMMARY

A method of treatment has been described for the obliteration of large bone cavities, following traumatic osteomyelitis in compound fractures. This method consists of three stages: (1) adequate sequestrectomy; (2) application of split-skin graft; and (3) excision of the initial skin graft, application of bone chips, and transfer of a full-thickness skin graft.

Thus far, of the twenty-three cases reported, the wounds in all but two cases have entirely healed. Bone sepsis has been eradicated in all cases of the series; and in all, the defects have been eliminated. There has been no sequestration of any of the chips, and no roentgenographic evidence of osteomyelitis following the insertion of the bone chips. In the two cases in which healing is not complete, the bone defects have been eliminated, bony union is solid, but the soft-tissue healing is not sound, because of error in the skin-graft technique, resulting in inadequate blood supply. Careful planning of the full-thickness skin-grafting will ensure sound healing.

NOTE: Expressions of appreciation are due Mr. L. R. Johnson of Cleveland, Ohio, for his untiring effort in taking and producing the photographs.

TREATMENT OF BENIGN GIANT-CELL TUMOR IN THE LOWER THIRD OF THE FEMUR BY CURETTAGE AND "TELESCOPING" THE FRAGMENTS OF BONE *

BY ROBERT W. JOHNSON, JR., M.D., AND JOHN LYFORD, III, M.D., BALTIMORE, MARYLAND

From the Division of Orthopaedic Surgery, The Johns Hopkins Hospital, Baltimore

Included among the conservative surgical procedures for treating benign giant-cell tumors in the lower third of the femur are resection of the involved area, followed by bone-grafting, and curettage and chemical cauterization, with or without the filling of the cavity with bone chips.

Since about 40 per cent. of all giant-cell tumors of bone occur in young adults, treatment which permits removal of the growth, and yet retains mobility of the knee, is desirable. Often, the cortical shell about the tumor is so thin that fractures occur; or the cavity is so large that the healing process is exceedingly long.

In 1936 a patient came to us suffering from a giant-cell tumor of the femur, which had undergone rapid enlargement during a recently concluded pregnancy. Extensive destruction had spread to the joint surface of the condyles, and a pathological fracture had already occurred. It was an especially difficult case, because the patient had to return very soon to her home in the Venezuelan oil fields, where her husband was employed. Therefore, any cure which we might be able to effect had to be as certain as possible, and every effort had to be made to retain function of the leg and knee joint, because in the isolated district where the patient's home was located medical attention would be practically unobtainable.

For a time, it seemed to us that amputation would provide the only solution. However, in an attempt to prevent this, we performed our first "telescoping" operation. This met with such prompt and permanent success that we have since employed it in a series of five similar cases. The authors offer it as an excellent compromise between the extreme conservatism of grafting procedures and the radicalism of amputation, which has been resorted to in so many cases.

OPERATIVE PROCEDURE

The operation is performed with a tourniquet. The involved area of bone in the distal end of the femur is exposed, and a window is cut in the thinnest part of the cortex. Through this opening, the tumor is removed by curettage, care being taken not to break through the articular cartilage into the knee joint, or through the posterior cortex. All soft tissues are carefully protected by sponges, and the cavity is cauterized with pure phenol, and washed out with alcohol. The remaining cortex is then carefully osteotomized, and the distal fragment is forced up around the end of the shaft of the bone, thus telescoping the fragments and filling the cavity with the end of the proximal fragment. Chromic catgut sutures are used to close the cortex and the periosteum as tightly as possible, to reapproximate the muscles, and to close the fascia tightly. The skin is closed in the usual manner. No packs or drains are used. A plaster hip spica is applied with the knee partially flexed. The tourniquet is removed after the cast has been applied to the leg.

The results in the cases in which this method was employed have been gratifying. There have been no instances of unusual bleeding, and no infections. Function of the knee after healing is good, and full weight-bearing on the leg is obtained. There is shortening of the leg by one to three inches (2.5 to 7.5 centimeters), depending upon the size of the cavity, but this is easily corrected by a lift on the shoe of the affected side, or even by

* Prepared for presentation at the Meeting of The American Orthopaedic Association, May 1945, which was cancelled in compliance with the request of the Office of Defense Transportation.

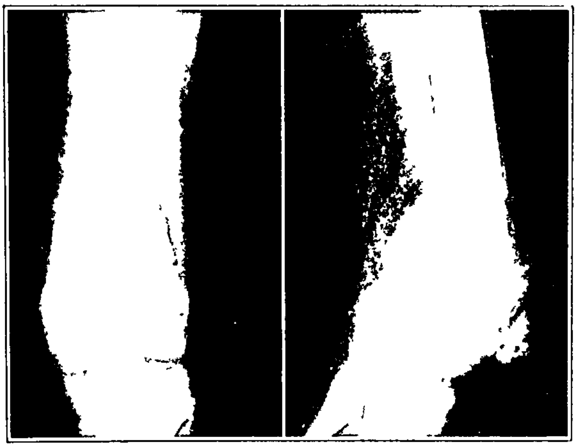

FIG. 1-A

Case 1. Preoperative anteroposterior and lateral roentgenograms of the left knee, showing tumor involving the distal end of the left femur, but with the articular cartilages intact.

FIG. 1-B

Roentgenograms of the left knee two months after operation, showing resection of the tumor, telescoping of the fragments, and the articular cartilages still intact.

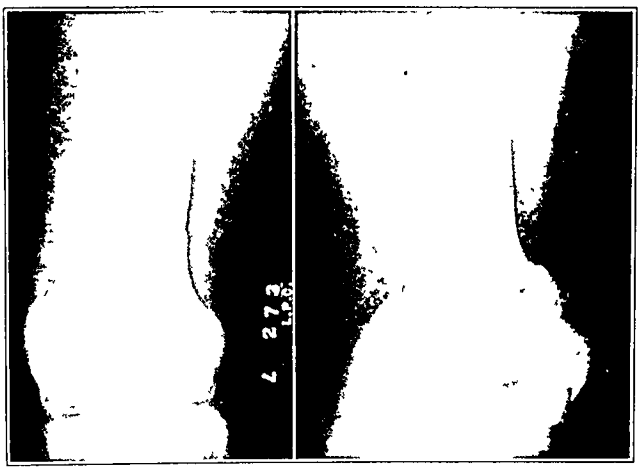

FIG. 1-C

Anteroposterior and lateral roentgenograms three years and nine months after operation, showing left knee with good healing of fragments and no evidences of recurrence of the tumor.

FIG. 2-A

Case 3. Preoperative anteroposterior roentgenogram of the right knee, showing extensive multilocular tumor involving the distal end of the femur, but with the articular cartilages intact.

operative shortening of the opposite leg. The healing time is somewhat longer than that for a comminuted supracondylar fracture of the femur. The position of the bone fragments is shown in the illustrations of the cases described.

CASE 1. S. M., a white woman, twenty-three years old, had had pain and swelling in the left knee for seven months, and had lost ten pounds in weight. Physical examination revealed atrophy of the thigh and calf muscles of the left leg, and a flexion deformity of the left knee of about 20 degrees. The patient could fully extend the knee, but with pain. There was a fusiform swelling involving the entire circumference of the shaft of the left femur just above the distal epiphysis. Roentgenograms showed a large mass, characteristic of a giant-cell tumor, involving the distal end of the left femur, but not affecting the knee joint. On July 8, 1936, the tumor was removed by curettage and carbolization; the fragments were telescoped; and the wound was closed without drains. Upon microscopic examination, the tissue removed at operation was found to be a benign giant-cell tumor. Serial roentgenograms revealed good healing, and four years after the operation the patient was living an active life in the tropics, with full function of the knee and leg. The final shortening was three-fourths of an inch.

CASE 2. I. J., a white woman, fifty-eight years old, had noticed pain and a progressive swelling of the right knee. Examination revealed a diffuse swelling of the right knee, and tenderness and limitation of motion. Roentgenograms revealed a mass, characteristic of a giant-cell tumor, involving the distal portion of the right femur, but the articular cartilages of the knee were intact. On May 17, 1937, the

FIG. 2-B

Lateral and anteroposterior roentgenograms of the right knee two months after operation, showing resection of the tumor, telescoping of the fragments, and the articular cartilages still intact.

FIG. 2-C

Roentgenograms of the right knee three years after operation, showing good healing of the fragments and no evidences of recurrence of the tumor.

tumor was excised by curettage, followed by cauterization of the cavity with pure phenol. The fragments were telescoped, and the wound was closed tightly without drains. Upon microscopic examination the excised tissue was found to be a benign giant-cell tumor. The postoperative course was uneventful, and on August 24, 1937, all immobilization was removed. The femur was clinically solid, and roentgenograms showed firm bony union. The final shortening was one inch (2.5 centimeters).

CASE 3. R. J. M., a white woman, twenty-two years old, fell on her right knee in January 1939, and had had persistent pain in the knee thereafter. In February 1940, she tripped again, and felt something snap in her right knee. Roentgenograms revealed in the distal end of the right femur a mass with the characteristics of a giant-cell tumor. The articular cartilages of the knee joint were intact. On August 2, 1940, the tumor was excised by curettage, followed by cauterization of the cavity with pure phenol and telescoping of the fragments. Microscopic examination showed the excised tissue to be a benign giant-cell tumor. The wound was closed without drains. After nine weeks the femur was clinically solid, and roentgenograms showed good bony union. Two years later the patient was bearing weight on the leg freely; there was satisfactory motion in the knee joint; and, upon roentgenographic examination, no evidence of reactivation of the tumor was found. The final shortening was three inches (7.5 centimeters).

CASE 4. V. C. W., a colored girl, twenty-eight years old, had had pain in the right knee for eight months following a fall on the knee on July 4, 1943. Physical examination revealed a generalized swell-

FIG. 3-A

FIG 3-B

Case 5. Preoperative roentgenograms, showing extensive destruction of cortex and medulla by tumor.

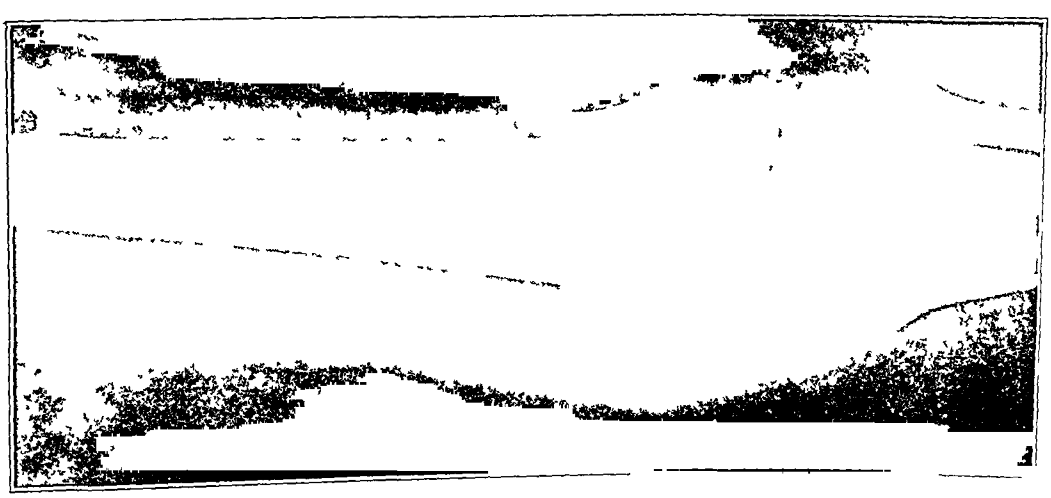

Fig. 3-C

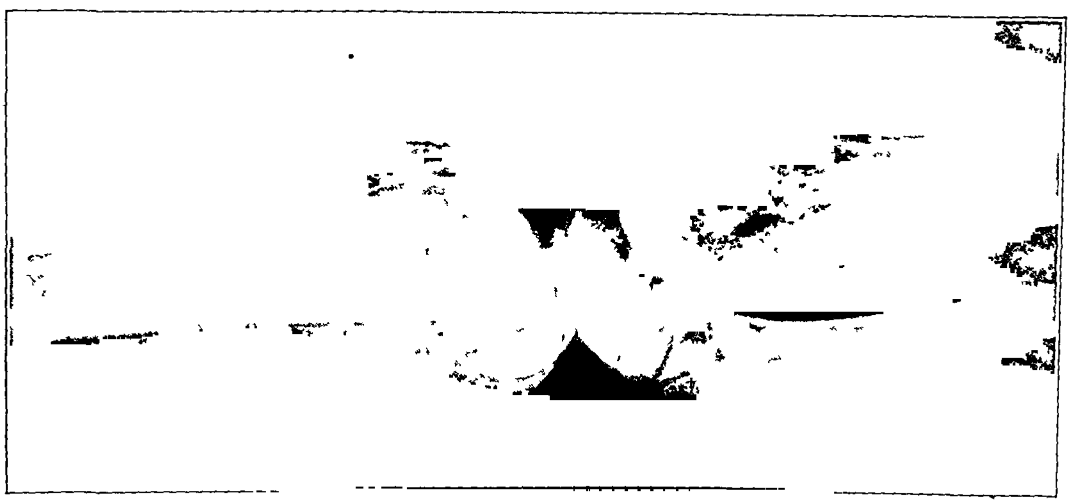

Fig. 3-D

Postoperative roentgenograms, showing immediate effect of telescoping.

Fig. 3-E

Roentgenograms, one year after operation, show healing with no sign of recurrence

ing about the right knee, most marked in the supracondylar area. Motion of the knee was limited to the range of 170 to 85 degrees. Roentgenograms showed a mass with the characteristic appearance of a giant-cell tumor occupying the distal end of the right femur, but not invading the knee joint. On March 20, 1944, the tumor was removed by curettage, followed by cauterization of the cavity with pure phenol. The fragments were telescoped, and the wound was closed without drains. The postoperative course was uneventful. Microscopic examination showed the excised tissue to be a benign giant-cell tumor. When the cast was changed twenty-four days after the operation, the wound was clean and well healed; and after nine weeks, union of the fragments was progressing satisfactorily. The final shortening was one and one-half inches (3.75 centimeters).

CASE 5. M. D., a white girl, twenty-five years old, complained of pain in the left knee, and of the formation of a bony mass of twelve months' duration. A marked increase in symptoms had occurred during the past five months. The examination showed the knee to be swollen to one and a half times the normal size. There was a firm mass, extending from two inches (five centimeters) above the joint line. There was muscle atrophy, and motion was restricted and had been painful since the patient had bumped the knee one month previously. There was no local temperature elevation. The roentgenograms revealed a large central tumor in the lower end of the femur which had broken through the cortex.

Before the operation, x-ray therapy was given. The operation was performed on June 3, 1943. When the tumor mass was excised, it was found to have eroded part of the anterior cortex, the medial, and the posterior cortex. Through the posterior cortex it extended into the popliteal space. Following osteotomy, the shaft was telescoped into the condylar dead space, filling it well. Microscopic section showed a benign giant-cell tumor. The wound was closed tightly, and a cast was applied. Healing occurred *per primam*. The cast was removed on September 28, 1943, and the femur was healing well. The patient was discharged on crutches, and graduated weight-bearing was begun. At present the patient reports excellent function, and the final shortening is not enough to require shoe alteration.

SUMMARY

There has been described an operation for the conservative surgical treatment of benign giant-cell tumors in the distal end of the femur, in cases in which the articular cartilages of the knee joint are intact. This method permits removal of the tumor, and yet retains mobility of the knee joint and the full weight-bearing function of the leg. The procedure consists of obliterating the cavity by telescoping the fragments of bone, after removal of the tumor by curettage and chemical cauterization. To date the patients (all women) have accepted the shortening incurred, and have declined our offers to equalize length by operative shortening of the normal limb.

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LOCAL CHEMOTHERAPY WITH PRIMARY CLOSURE OF SEPTIC WOUNDS BY MEANS OF DRAINAGE AND IRRIGATION CANNULAE

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INTRODUCTION

The fundamental principle in the treatment of deep sepsis is the creation of a path or preferably an avenue of escape for the accumulated products of infection. "Packing the wound open" is the method generally used to accomplish this purpose, but it has many drawbacks. Making a wound close from the bottom means a prolonged period of healing, during which time there is bound to be considerable loss of serum from the granulating surfaces; this fact alone is a serious objection to drainage by packing the wound open. Relatively frequent dressings, painful to the patient, and time-consuming for the surgeon, are another objection to the method. Partial primary closure of the wound is the logical answer to this problem.

HISTORICAL BACKGROUND

Development of Drainage and Irrigation Cannulae

In 1934 the first "drainage and irrigation cannulae" (Fig. 1) were made for the Osteomyelitis Service of the Massachusetts General Hospital. These were straight glass cannulae, each with a flange at one end to prevent it from slipping out of the wound. After incision and drainage of an osteomyelitic area, two of these cannulae were inserted, and the wound was closed tightly around them. Rubber tubes were connected to the cannulae,—one leading to a bottle of irrigating fluid at the head of the bed, the other to a waste bottle on the floor. At regular intervals, irrigation fluid was allowed to flow through the wound until it came out clear; the rubber tube from the outlet cannula was then clamped off, allowing the irrigation fluid to accumulate in the wound before the rubber tube from the supply bottle was clamped off. Dakin's solution was the agent used both for its cleansing and for its bacteriostatic effect.

Several members of the Osteomyelitis Service did not look with favor upon this method of treatment, and the orthopaedic surgeon responsible for the treatment did not feel any too confident; consequently, the cases treated in this manner were few and far between, and progress was proportionally slow.

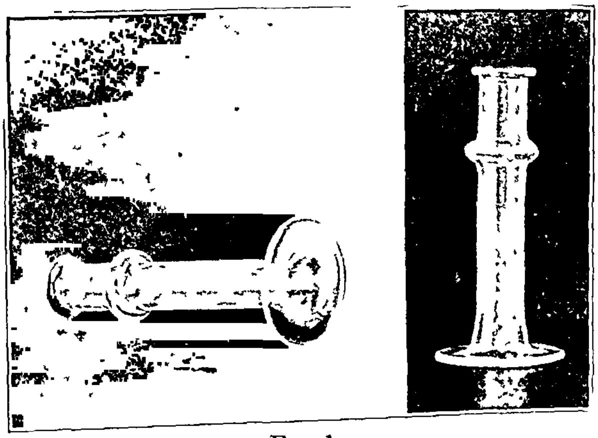

FIG. 1

Original glass drainage and irrigation cannulae (February 1934).

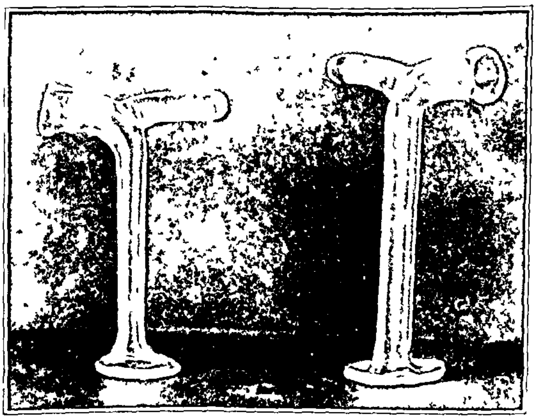

FIG. 2

Modified glass cannulae: elliptical, neck bent, strut added (April 1935).

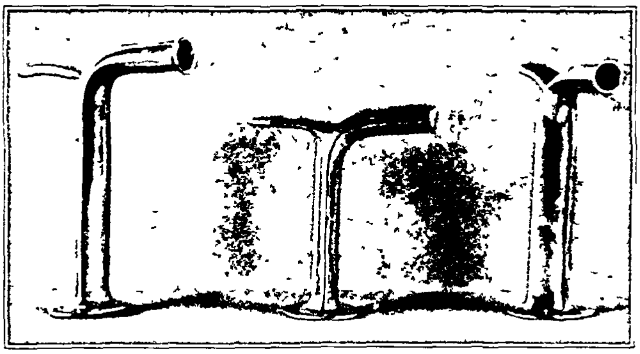

FIG 3
Vitallium cannulae, present models (1938).

It was soon found that the round glass cannulae allowed leakage, and also caused pressure necrosis of the skin edges. Furthermore, they teetered sideway, and were apt to slip down against the bony floor of the cavity. These difficulties were gradually overcome; the cannula was made elliptical to avoid leakage and pressure on soft parts (Fig. 2), the neck of the cannula was bent at a right angle and a strut was added. These changes permitted stabilization of the cannula by providing space in which to pack gauze between the skin and the neck and strut (Fig. 2). Glass was not ideal because of the possibility of breakage; so, in 1938, the first vitallium cannulae were made (Fig. 3). Only minor changes in shape and caliber have been made since that time.

Irrigation Fluids and Chemotherapeutic Agents

Dakin's solution has been used extensively from the very first, and even now it is often substituted temporarily for other chemotherapeutic agents.

Silver-pectinate solution has been used in a limited number of cases as a local chemotherapeutic agent, but not as an irrigation fluid.

Penicillin has been used for the last year. The system of two drainage and irrigation cannulae has been found to be a very practical way of introducing the penicillin locally (Figs. 4 and 5).

TECHNIQUE

After primary closure of the wound around the cannulae, gauze sponges are packed between the skin and the neck, as well as between the skin and the flange or strut (Figs. 6 and 7). This packing stabilizes the cannulae and prevents them from teetering; it also keeps the deep portions of the cannulae away from the floor of the septic area. Additional dressing is applied, and held in place by an elastic bandage. By introducing a certain number of cubic centimeters of air through a syringe, a corresponding amount of fluid is delivered from the supply bottle into the wound through the inlet cannula. The outlet cannula is left open until clear fluid appears; then it is clamped off.

When penicillin is used as the local chemotherapeutic agent, the amount decided upon is delivered into the wound by the above technique every four hours. The strength of the solution up to the present has been 250 units per cubic centimeter. The period of local administration of penicillin has varied from a minimum of two weeks to a maximum of four weeks. It is decided upon on the basis of the extent and the duration of the sepsis, preoperatively, as well as the clinical course postoperatively. If at any time a change in the local chemotherapeutic agent is indicated, the system is kept intact except for the supply bottle and its contents. Indications for such a change are: secondary infection, such as *Bacillus coli* or other penicillin-resistant organisms, or interference with the flow of penicillin through the septic area. Dakin's solution has been the only chemotherapeutic agent used as a temporary substitute for penicillin. Dressings are infrequent,—the dressing applied at the time of operation is frequently left undisturbed for a week or ten days; local discomfort from a sticky, bloody dressing may demand a change as early as three or four days after operation, but, after this initial change, there may be no indication for dressings until the cannulae are removed.

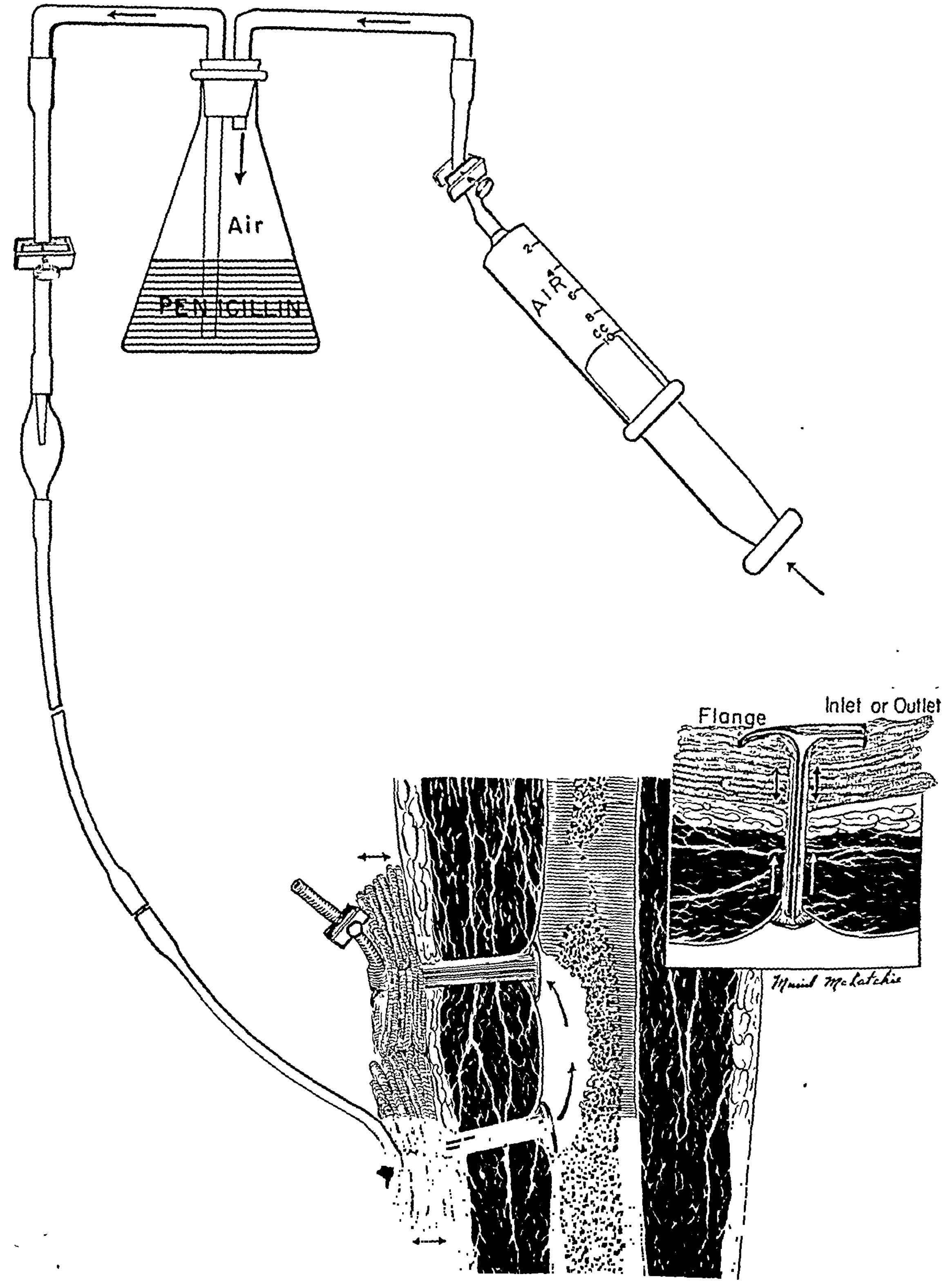

Fig. 4

Diagrammatic representation of the use of cannulae in connection with a closed system for the local administration of penicillin.*

Removal of Cannulae

During the developmental stage, the cannulae were removed under local anaesthesia at the end of two to four weeks, without any attempt being made to close the soft-tissue defects created by them. Consequently, dressings were necessary for varying periods of time, but they were minor, not time-consuming and not painful. Since the advent of penicillin, the technique has changed only slightly: The cannulae are still being removed

* This closed system of local administration, as now used, originated with two Surgical Residents, Grant Rodkey, M.D., and Richard Webster, M.D.

at the end of two to four weeks, usually under pentothal anaesthesia, but the soft-tissue defects are closed, leaving only a small rubber catheter in place for the administration of penicillin for a few more days. This use of the catheter is a sign of lack of faith in nature's ability to combat residual infection successfully; cultures taken at the time of the removal of the cannulae invariably show bacterial growth.

Systemic Chemotherapy

Bacteraemia and septicaemia are ever-present threats accompanying local infection. Systemic chemotherapy has made miraculous progress during the last few years, and it would be poor judgment indeed to confine ourselves to the use of local chemotherapy. Systemic penicillin has been administered for a minimum of twenty-four hours before operation, throughout the period of local chemotherapy, and for a few days to a week following the removal of the cannulae; 100,000 units per twenty-four hours has been the usual dosage.

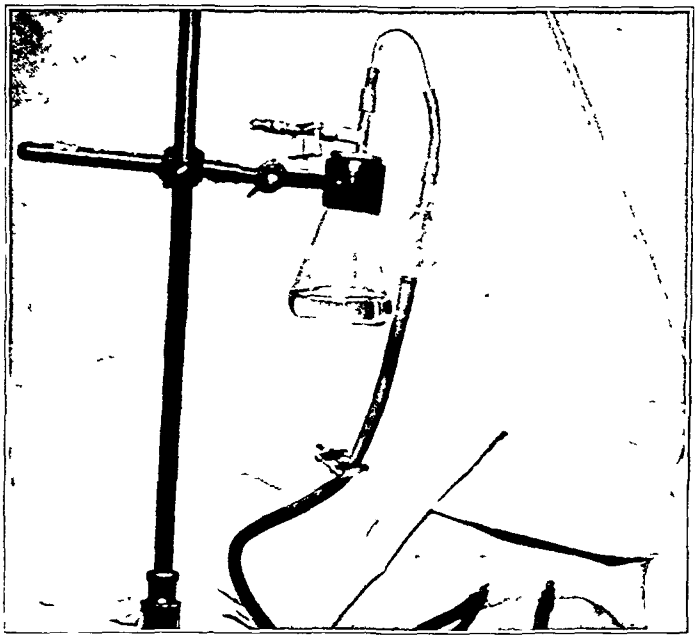

Fig. 5
Apparatus in use in a case of hip-joint sepsis.

Variations in Technique

The number of cannulae at our disposal has been and still is very limited. Consequently, there have been occasions when no cannulae were available; at such times rubber catheters have been used in their place. The technique of wound closure and local instillation of penicillin has been the same as that employed with the cannulae. Rubber catheters clog more easily, and may cause local reaction.

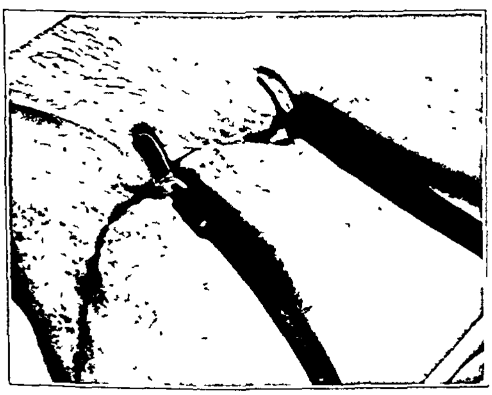

Fig. 6
Close-up view of cannulae in place twelve days after insertion. Very minor local reaction.

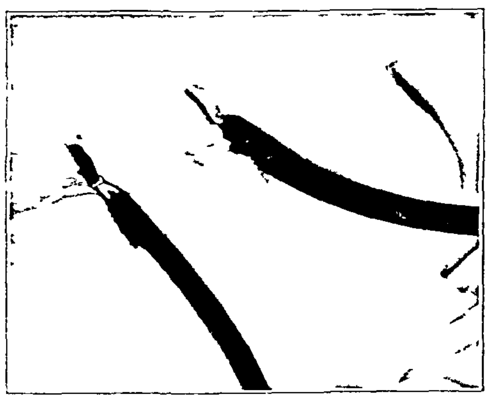

Fig 7
Same case as Fig. 6. Packing in place.

CASE REPORTS

This is a preliminary report of a method of local treatment of sepsis. Our experience with it has been so favorable that we feel justified in submitting it for trial. It has not

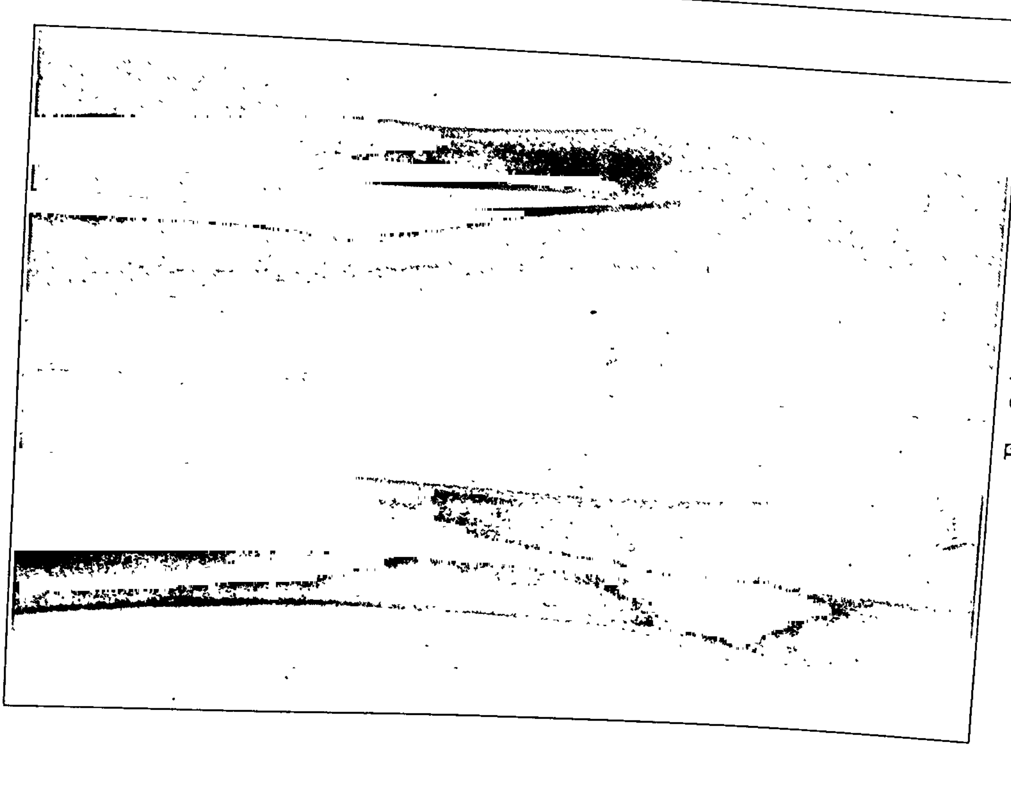

Fig. 8-A
Case 1. Osteomyelitis of the left fibula before operation.

Fig. 8-B
Roentgenogram after saucerization and insertion of glass cannulae.

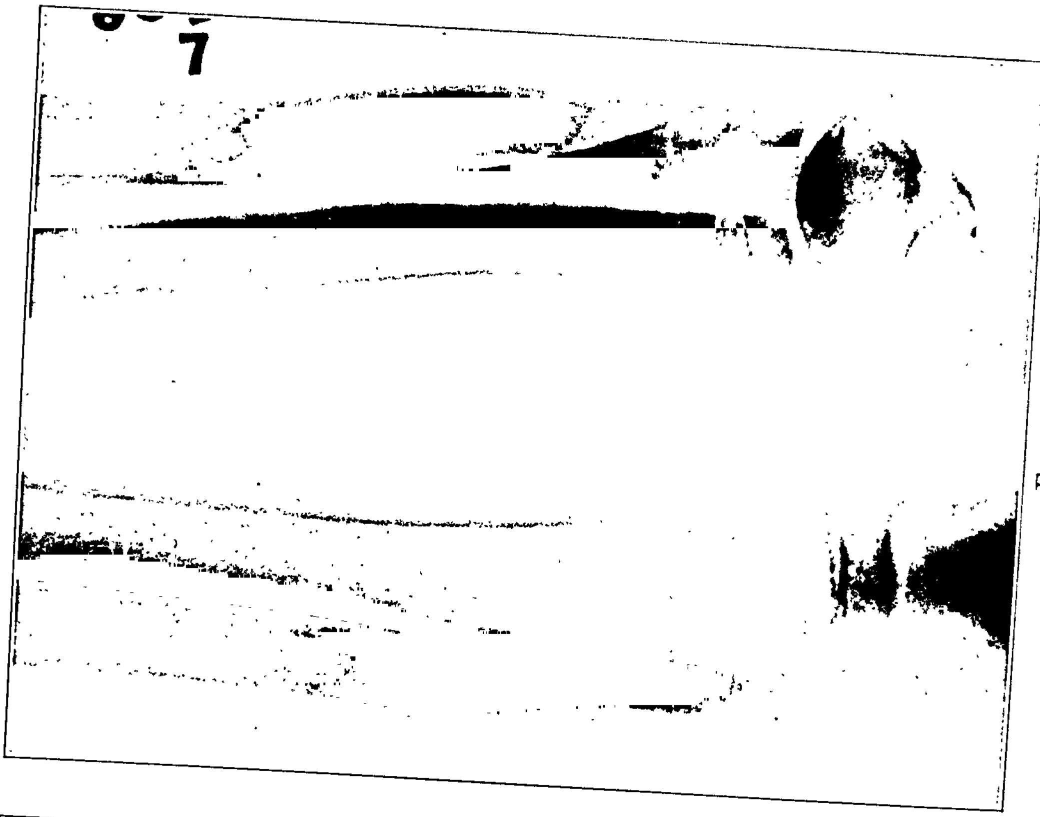

Fig. 8-C
Roentgenogram eight weeks after original operation,—six weeks after removal of cannulae.

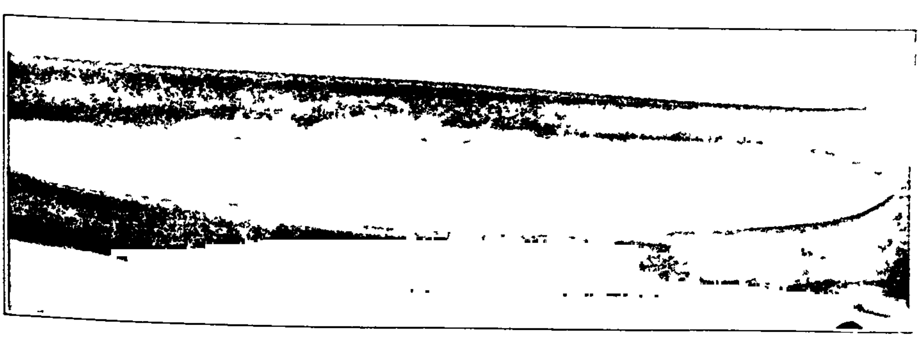

Fig. 9-A
Case 2. Osteomyelitis of right ulna before operation. March 1931.

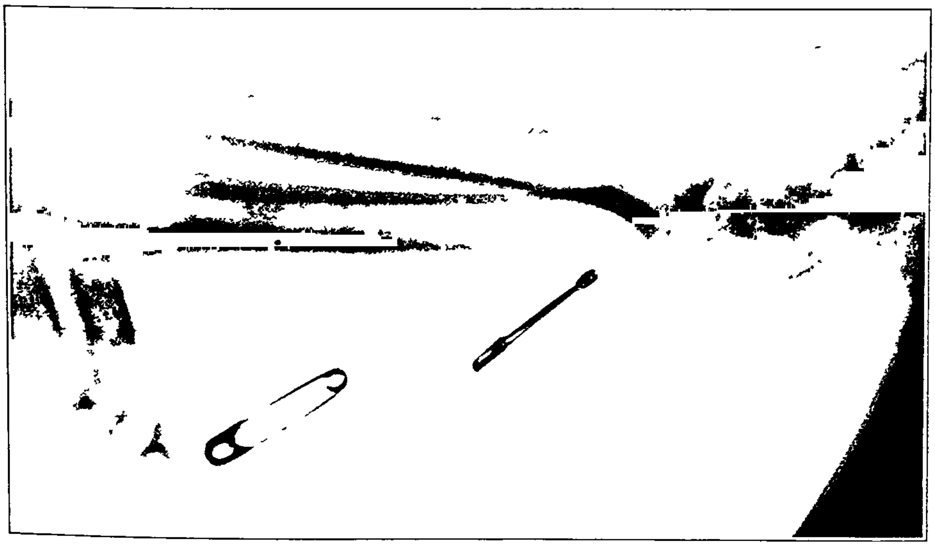

Fig. 9-B
After operation,—saucerization, insertion of glass cannulae, and closure of wound.

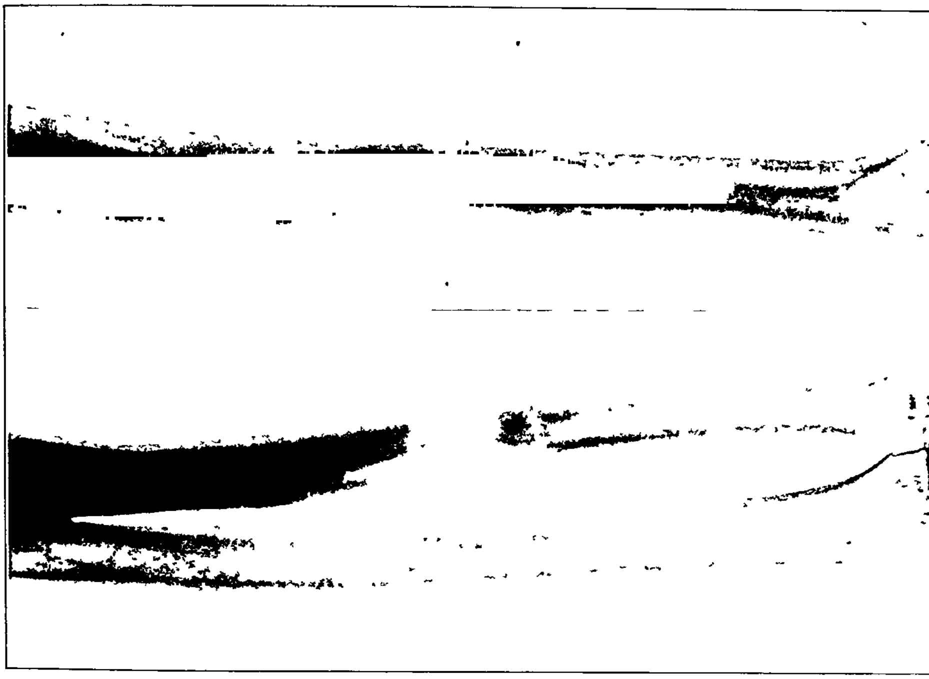

Fig. 9-C
After removal of cannulae. Wound healed in five weeks. No local recurrence.

been used in combination with systemic chemotherapy for a long enough period to allow an end-result study.

Three of the early cases are reported. They were selected not only because they are favorable, but also because they are typical. The roentgenograms are reproduced from lantern slides, since the films are no longer available.

One case, treated by systemic and local penicillin, is reported as an illustration of the present method.

CASE 1. A boy of thirteen had recurring osteomyelitis of the left fibula of two and a half years' duration (Fig. 8-A). At operation saucerization was performed, and two glass cannulae were inserted (Fig. 8-B). The cannulae were removed under local anaesthesia twelve days later, without repair of the

FIG. 10-A
Case 3. Old septic hip with lipiodol injection of sinus.

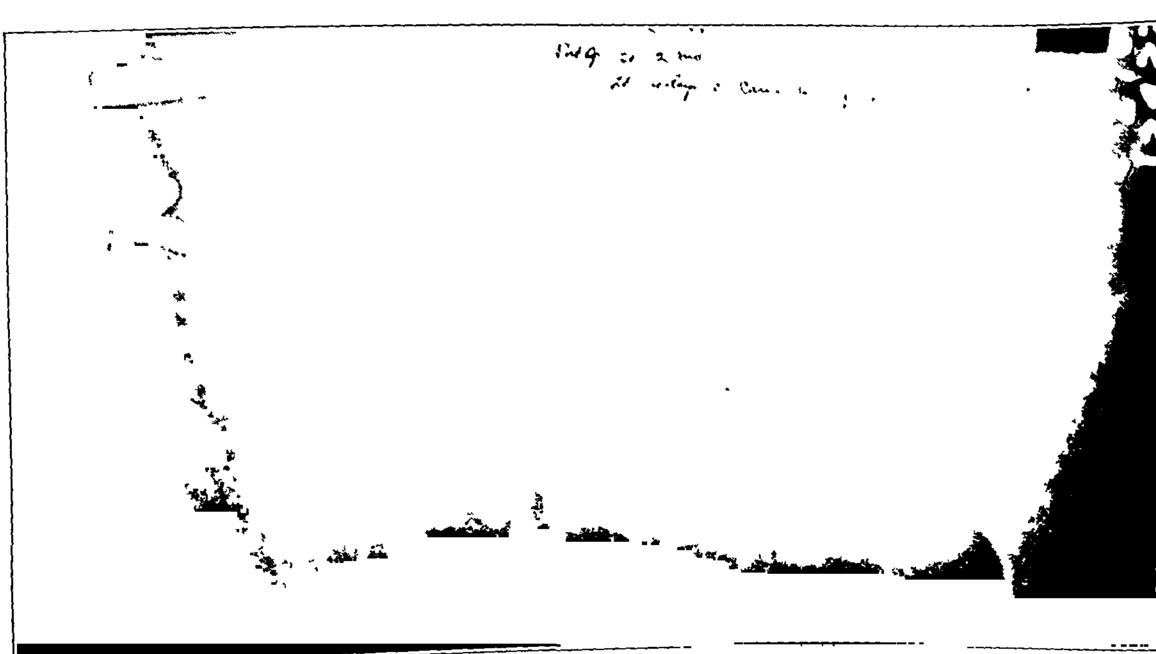

FIG. 10-B
Old septic hip after vitallium-mold arthroplasty and insertion of two vitallium cannulae.

FIG. 10-C
Seven months after removal of cannulae. Wound healed. No recurrence of sepsis.

skin defects. The wound healed completely in one month. Roentgenograms, made eight weeks after the operation, showed satisfactory bone repair, with no sequestra, and no areas suggestive of persistent infection (Fig. 8-C).

This was one of the cases treated during 1934, the first year the cannulae were used. Almost eleven years have elapsed without any recurrences.

CASE 2. A student of twenty-four had recurring symptoms referable to his right ulna. Roentgenograms (Fig. 9-A) showed changes characteristic of osteomyelitis. Operation in 1934 consisted in sequestrectomy, saucerization, and the insertion of glass cannulae (Fig. 9-B). The wound healed completely in five weeks (Fig. 9-C). There was no local recurrence, but several secondary foci developed during the nine years following this initial focus.

CASE 3. A man, thirty-eight years old, had rheumatoid arthritis, with a rigid spine, and fibrous ankylosis of both hips. In 1934 he had had a fascia lata arthroplasty of the left hip, with postoperative sepsis, which had persisted for five years (Fig. 10-A).

In December 1938 a vitallium-mold arthroplasty was performed on the right hip. Two months later, in February 1939, a vitallium-mold arthroplasty was performed on the left hip, and free pus was encountered in the iliac fossa. Two vitallium cannulae were inserted, and the wound was closed around them (Fig. 10-B). One month later the cannulae were removed (Fig. 10-C).

At the time of the patient's discharge from the Hospital, the wound was healed, and there has been no recurrence of sepsis up to the present, a period of six years. The patient has fair function of both hips, and is working at a job requiring standing from four to six hours a day.

CASE 4. A student of nineteen had multiple foci of osteomyelitis, occurring over a period of seven years. In July 1944, acute symptoms from a new focus, in the mid-shaft of the right femur, developed (Fig. 11-A). Operation included saucerization, and insertion of two vitallium cannulae, with wound closure (Fig. 11-B). Free pus was encountered in the medullary canal The postoperative course was smooth. The patient was particularly appreciative of the absence of painful dressings, because of his previous experience with them.

Systemic penicillin, 100,000 units in twenty-four hours, was administered for ten days after operation, and for a week after the removal of the cannulae. Local penicillin was injected every four hours · ten cubic centimeters, 250 units per cubic centimeter. This was continued up to the time of the removal of the cannulae.

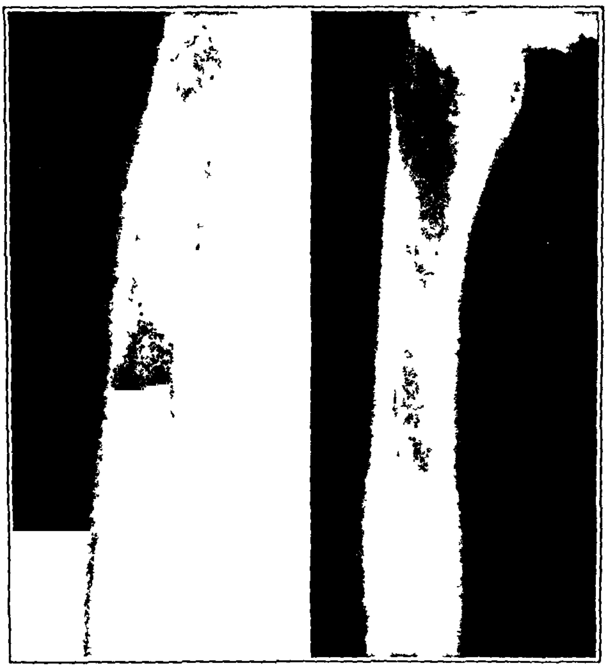

Fig. 11-A

Case 4. Osteomyelitis in mid-shaft, right femur. Preoperative roentgenograms.

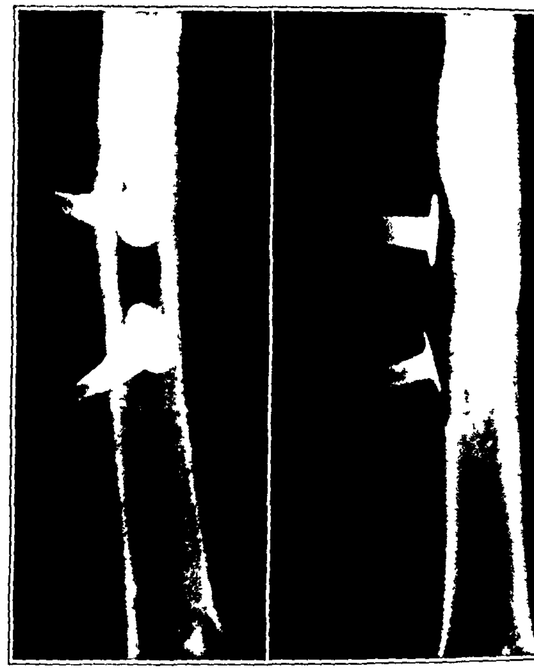

Fig. 11-B

Postoperative roentgenograms, showing vitallium cannulae in place. Note how the dressing prevents the cannulae from resting on the floor of the saucerized area.

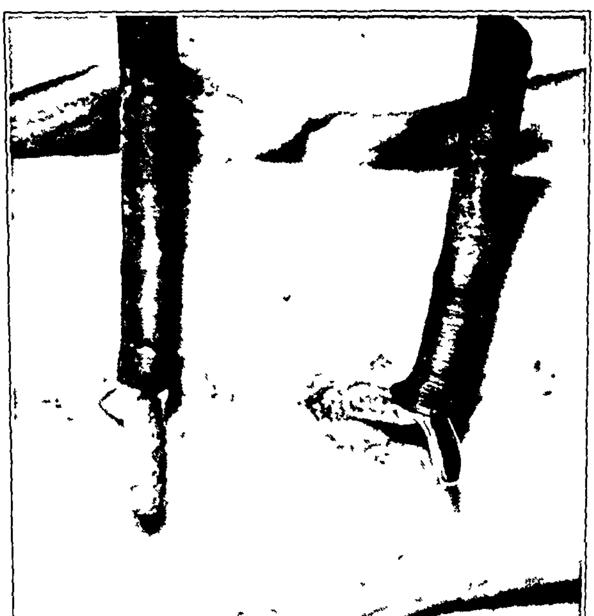

Fig. 11-C

Photograph of wound twenty-six days after insertion of the cannulae, just before their removal.

Fig. 11-D

Roentgenograms, six weeks after the original operation. Satisfactory progress of bone repair. Wound entirely healed.

The cannulae were removed on the twenty-sixth postoperative day (Fig 11-C) under pentothal anaesthesia, and the defects were closed. A small rubber catheter was left in place, and penicillin was continued locally for ten more days.

The wound was entirely healed six weeks after the original operation. Roentgenograms at that time showed satisfactory progress of bone repair (Fig. 11-D).

Only ten months have elapsed since operation, but so far there has been no local recurrence of sepsis.

DISCUSSION

Favorable Aspects

Looking back upon eleven years of experience with local chemotherapy, administered through a closed system of cannulae, several favorable aspects stand out. The almost

complete primary closure reduces to a minimum the loss of serum from the granulating surfaces. This is important because the loss of serum protein can be considerable, as was demonstrated in one case treated by the method of "packing the wound open". The determined loss of serum protein for one period of twenty-four hours amounted to 36.9 grams; the average daily loss over a period of a week was 11.9 grams. True, this was not an average routine case, but it serves to emphasize the importance of reducing granulating surfaces to a minimum.

The infrequency of dressings appeals to the patient and to the surgeon. Septic dressings are painful, no matter how gently they are done; and they are bound to be time-consuming.

The time for complete healing of the wound is materially shortened; and the scar is linear and level, instead of broad and puckered.

The postoperative clinical course in the majority of cases treated by this method has been smooth: the temperature chart levels off quickly; the patients are happy and look well.

Unfavorable Aspects

This is not a perfected method with 100 per cent. cures. There have been cases with local recurrence of sepsis, but these have been relatively few.

No matter how carefully the cannulae are sutured in place and stabilized by proper packing, local reaction from pressure and slight motion is apt to occur. Such reaction is very slight and easily excised at the time of the removal of the cannulae.

The drainage and irrigation system is not immune to clogging. A change in fluid and flushing the wound usually eliminate obstructions without much difficulty.

Penicillin

With the great advances that have been made in chemotherapy in recent years, particularly since the advent of penicillin, a wider application of this method of treatment is possible. So far our experience has been limited to osteomyelitis of the extremities and bony pelvis. As further knowledge is gained regarding the effectiveness of penicillin and other chemotherapeutic agents, it becomes less and less hazardous to eliminate, partially or completely, soft-tissue defects in the presence of potential or even active sepsis. Topical application of the chemotherapeutic agents seems an important factor for success, and the cannulae are an efficient means of administering such treatment.

CONGENITAL ABSENCE OF THE RADIUS

A Method of Surgical Correction

BY D. E. STARR, M.D., VANCOUVER, BRITISH COLUMBIA, CANADA

Congenital absence of part or all of the radius has been reported by many, and methods of dealing with the deformity have been described by well-known authors.

In 1905, Antonelli reported 114 cases, and declared at that time that the deformity was more often single than double, and that it occurred more often as the result of partial absence of the radius, usually the distal end, than as the result of complete absence. Kümmel described the total absence of the radius in detail.

HISTORICAL BACKGROUND

Previously reported techniques are numerous. Sayre preceded his surgical correction by adhesive skin traction, in an attempt to overcome the radial deviation of the hand in relation to the lower end of the ulna. He then inserted the distal end of the radius into the carpus, from which some of the bones were removed. According to Kermisson and Langet, muscles on the radial side of the hand are usually missing. McCurdy, in his procedure, tenotomized the short tendons on the radial side, then severed the ulna at a point where the free end of the upper fragment could be brought into contact with the carpal lunate, which was curetted and fixed to the graft with silkworm gut. Bardenheuer split the ulna, and then allowed the carpus to fit into the bifurcated portion, fixing the bifurcation to the carpus with two ivory bone pegs. Tubby modified this procedure by using silkworm-gut fixation, instead of the ivory bone pegs. A kangaroo tendon was used by Rosswell Park for the same purpose. Ryerson described a technique in which a graft was removed from the ulna, and used as a radial shaft with fixation to the carpal region. No adequate fixation of the upper end of the graft was attempted. Albee used a tibial graft which he strutted from the ulna into the carpal bones. Steindler tenotomized the contracted radial tendons, and then did an osteotomy at the maximum bowing of the ulna. A bed was then prepared in the carpus, and the epiphysis was removed from the lower end of the ulna. The ulna was then pointed and inserted into the cleft in the carpal bones midway into the metacarpal region, and fixed with chromic catgut through drill holes. Campbell suggested a similar technique to Steindler's, but stated that the operative treatment should not be done before the patient has reached two years of age.

Treatment by manipulation and plaster fixation has also been attempted. Hassel described a simple osteotomy of the ulna. Romans described a cuneiform osteotomy in which the ulna was sutured to the carpus.

As far as one can gather, there appears to be no utilization of skeletal traction in preliminary correction of the deformity. Transplantation of the fibula to the forearm has been done to replace the previously resected radius, but not for congenital absence. Campbell described the insertion of the lower end of the radius for resected tumor masses involving the lower radius. The technique of removal and replacement has been described by Schauffler, where involvement of the humerus at the upper end was encountered.

METHOD

The segmental defect as seen and characterized by the absence of the radius is frequently associated with other congenital deformities of the same limb. It is extremely frequent to find absence of the first metacarpal, with or without absence of the thumb, and of the radial component of the carpal bones. Corresponding soft parts may be absent.

In attempting this new procedure, an effort was made to correct soft-tissue deformity before attempting bony correction, and to preserve the growing function of the remaining

ulna, which is already grossly shortened. It provides a means of allowing some freedom of the carpal bones, and, if possible, wrist motion. It was also possible to maintain moderate rotary motion of the forearm, where any portion of the upper end of the radius remained.

The metacarpal heads, therefore, were transfixed with a Kirschner wire, as was the olecranon, and Dunlop traction was applied to distract the forearm, at the same time directing the hand to the ulnar side (Fig. 2-C). Traction for six weeks stretched the soft tissues distal to the lower end of the radius. Traction also brought the remaining carpal bones into a position relatively distal to the lower end of the ulna.

An oblique osteotomy was then performed in the ulna, and the traction was maintained until union had occurred at the site of the osteotomy. Unfortunately, in the first instance, the osteotomy was too distal, and only part of the bowing of the ulna was corrected.

Fig. 1-A

Infant showing bilateral congenital absence of radius. Note bilateral absence of first metacarpal bone, and absence of thumb on the left.

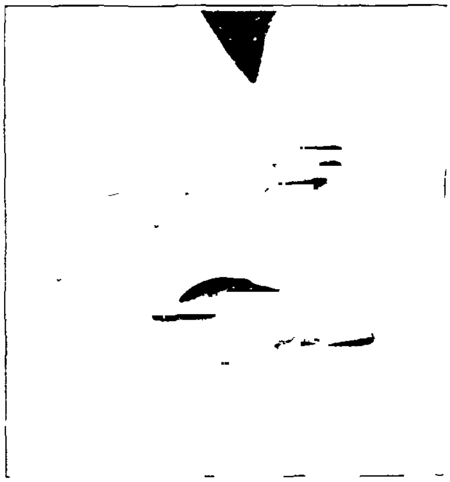

Fig. 1-B

Maternal grandmother, showing absence of right thumb and presence of thumb with three phalanges on the left.

When thorough union had occurred, the Kirschner wires were removed, and the forearm was placed in plaster.

A third stage was then performed. The upper end of the fibula was removed extraperiosteally, and was transplanted to the forearm. Special care was taken to dissect the upper end of the fibular transplant in such a manner that the epiphyseal periosteum was not disturbed. The soft-tissue mass distal to the radius was removed, and this in part made room for the transplant. No difficulty was encountered in inserting the graft between the flexor and extensor tendons, although all the normal structures were not present, nor in maintaining the upper articular surface of the fibula in contact with the remaining carpal bones.

CASE REPORTS

The author has seen congenital absence of the radius in its various aspects in three cases, involving four limbs. Most interesting was a bilateral case with complete absence of the radius, the thumb, and the first metacarpal bones. Correction was not attempted because of the patient's age (Fig. 1-A). The maternal grandmother showed an absence of the first metacarpal and thumb on the right hand; while on the left, the thumb had three phalanges (Fig. 1-B).

FIG. 2-A
Case 2. Photograph of arm before correction.

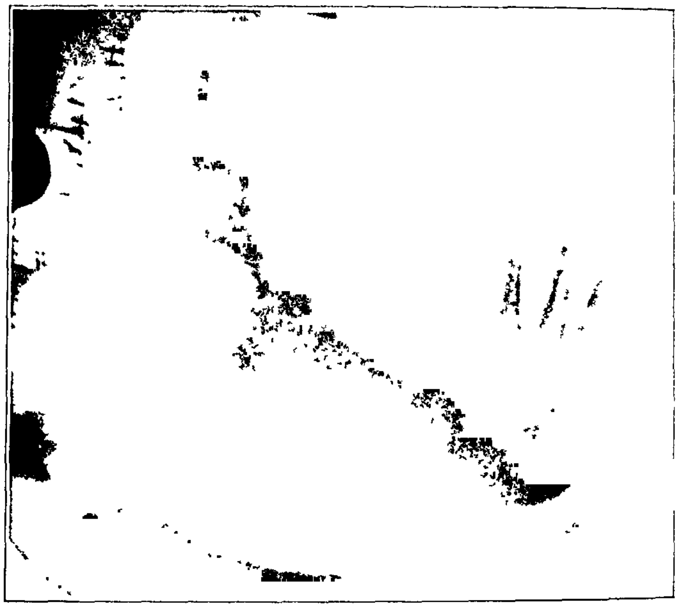

FIG. 2-B

Fig. 2-B: Roentgenogram of arm before correction.

Fig. 2-C: Photograph, showing arm in skeletal traction.

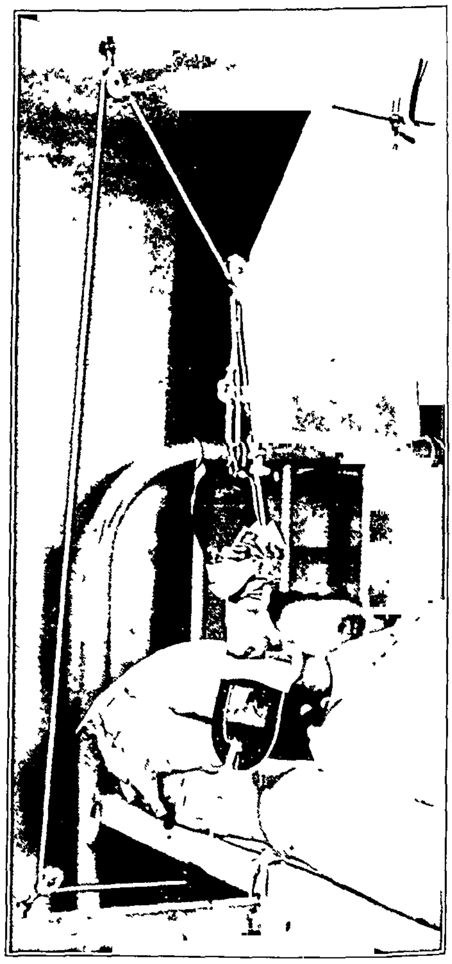

FIG. 2-C

The other two patients, showed partial or complete absence of the radius. Both of these patients showed absence of some of the carpal bones, as well as the first metacarpal; one with a non-articulated thumb composed of two digits, the other without any evidence of a thumb.

This series comprises the usual variations found in this deformity, which is disabling and very unsightly. The forearm is short, the ulna is always bowed, and the hand is in extreme valgus. There is usually no wrist articulation, since the ulna is dislocated distal to the carpus. The absence of the thumb is also incapacitating.

CASE 2. This child was first seen at the age of ten years (Fig. 2-A). She was small of stature, but apart from the right forearm, was normally developed. There was no history of congenital deformity in the family. The method described was first carried out on this patient. There was not a complete absence of the radius. The lower end was atrophied, and the radius terminated in the lower third of the forearm in an irregular, pointed mass (Fig. 2-B). The space taken between the carpal bones, chiefly the ulnar components, and the distal end of the radius, was filled with a soft cartilaginous mass. The radius was markedly short and atrophied in comparison with the ulna. The ulna, definitely bowed, was grossly shortened in comparison with the normal arm, and did not articulate with the carpal bones.

The usual procedures did not seem applicable in this case, so it was decided to use what remained of the radius and to construct a lower radial graft, which would give a more permanent and more flexible correction. The free end of the transplant was tapered to dovetail with the freshened surface of the lower end of the radius.

The hand, forearm, and arm were then placed in plaster and maintained in fixation for ten weeks.

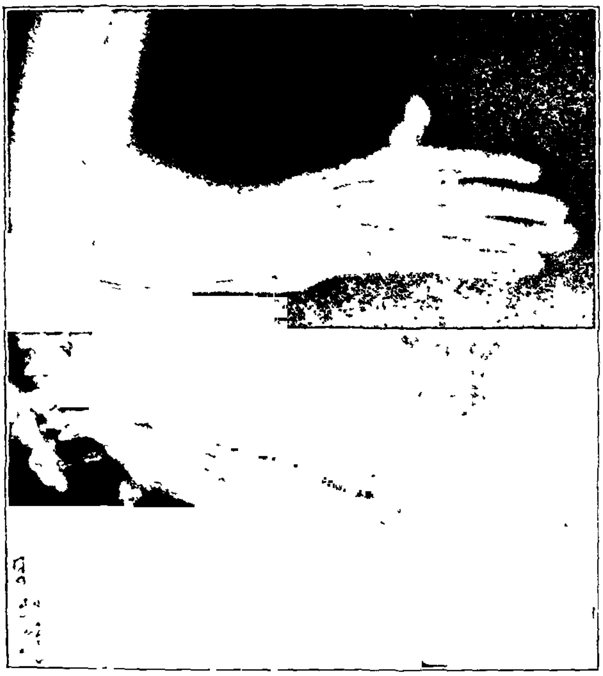

Fig. 2-D
Roentgenograms one and a half years after fibular transplant. Note patent epiphysis in transplant.

Fig. 2-E
Photograph one and a half years after correction.

The forearm exhibited the usual radial contractures, and could not be corrected manually more than 15 degrees. It was obvious, therefore, that no more than 15 degrees could be obtained as the result of the operation. This meant considerable persistent deformity. Surgical correction of this deformity has not, in general, resulted in much improvement, either cosmetically or functionally, other than a slight stability of the forearm and hand. The deformity has not been well corrected.

Follow-up roentgenograms revealed good union between the radius and the shaft of the transplanted fibula with what appeared to be a patent epiphysis.

The recent roentgenograms and photographs represent the follow-up of one and a half years (Figs. 2-D and 2-E). Pronation and supination are each 50 per cent., and there is also wrist motion.

Criticism should be made of the procedure in two respects. The transplant was somewhat too short, and a longer one could have been applied without difficulty. It will also be noted (Fig. 2-D) that there is still some persistent bowing in the upper third of the ulna. It is contemplated that this might be corrected by subsequent osteotomy of both bones, and further skeletal traction. These errors were rectified in the next case attempted.

Case 3. This child was first seen at the age of twelve, at which time a deformity of the right forearm was noticed (Fig. 3-A). There was a complete absence of the radius, some of the radial components of the carpus, and of the first metacarpal and thumb. The opposite forearm was normal. There was also marked radial angulation of the hand, and dislocation of the carpus in relation to the lower end of the ulna, which was prominent dorsally and ulnaward. A large skin callus had developed over the prominent lower end of the ulna. The child was wearing a molded leather and metal support to help maintain the hand in improved relationship.

In this case, a similar operative procedure was attempted except that, since no radius was present, the graft was inserted into the ulna at the approximate site of the osteotomy. Skeletal traction was applied for six weeks. A remarkable realignment of the hand in relation to the forearm was obtained. Osteotomy was then accomplished in the ulna at the site of maximum bowing, and was transfixed with Roger Anderson external fixation, including the Kirschner wire.

This, it was felt, was a luxury, but maintained the hand and arm in good correction. It is unnecessary, providing the arm is kept in skeletal traction while the osteotomy unites.

Upon complete union of the ulna, removal of the pins, and the healing of the pin sites, the third stage was attempted two months after the osteotomy.

No difficulty was encountered in inserting the transplanted upper end of the fibula in relation to

the carpus. There was, however, slight diastasis between the lower end of the ulna and the transplanted fibular graft. It was maintained by two vitallium screws placed transversely through the forearm, one at the site of insertion in the ulna, and the other in the distal half (Fig. 3-D).

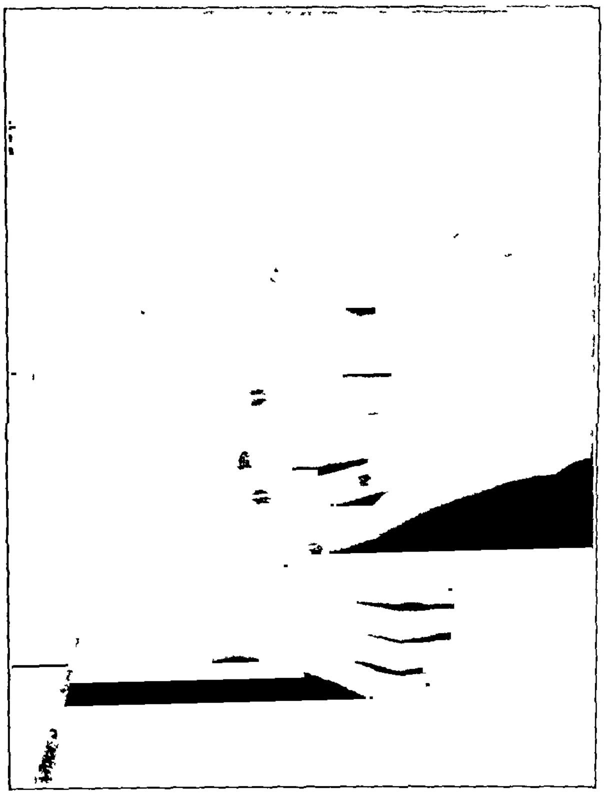

Fig. 3-A
Case 3. Photograph before correction.

Fig. 3-B
Roentgenograms before correction.

Fig. 3-C
External fixation following osteotomy.

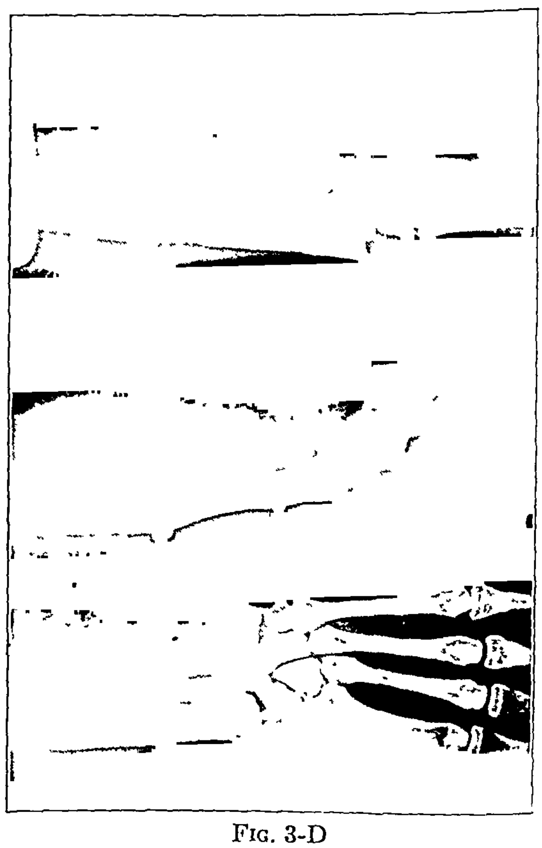

Fig. 3-D
Roentgenograms one year after final stage of correction.

FIG. 3-E
Photograph taken one year after final stage of correction.

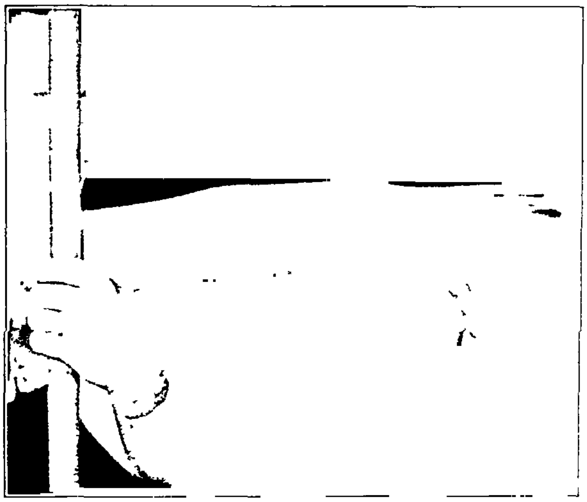

FIG. 3-F
Photograph showing wrist motion.

In this case, the correction has been better than in the first one attempted. It does not appear, however, that the epiphysis of the fibula has remained patent; but, after one year, there is no discrepancy in the length of the lower end of the ulna in relation to the transplanted fibular graft. Flexion and extension of the wrist are possible (Fig. 3-F). There has been no tendency to recurrence of the radial deviation. The forearm at the time of the third procedure was aligned in mid-pronation. The functional end result in this case is excellent, although no rotary motion of the forearm is obtainable.

SUMMARY

1. Congenital absence of the radius, while uncommon, has been repeatedly reported in the literature.

2. The deformity is often accompanied by other evidences of congenital deformity of the hand, and, in one case, a direct hereditary linkage with the maternal grandmother is shown.

3. The technique described is a three-stage procedure,—namely, skeletal traction, ulnar osteotomy, and fibular transplant.

4. The technique is unique in allowing forearm rotation and wrist motion, when part of the radius is present; and it results in an extremely improved appearance.

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BRITTAIN ISCHIOFEMORAL ARTHRODESIS

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In 1941, Brittain described a method of arthrodesis of the hip, in which a large tibial graft is inserted into a cleft in the ischium, through an oblique osteotomy. The shaft of the femur is then displaced medially toward the ischium, supporting the graft and "short-circuiting" the diseased hip joint. Brittain, in his original paper[1], reported thirty-five cases of hip-joint disease in which arthrodeses were done by this method, with success in 88 per cent.; re-fusion by the same method was necessary in three cases. In Brittain's series, sixteen cases were of infectious or osteo-arthritic origin, while nineteen were cases of tuberculosis.

This method of arthrodesis utilizes the principle that, for stability and bone growth, compression is more efficient than tension[2]. Atrophy of the soft parts on the medial side of the thigh, which occurs during immobilization in a cast, places a strain on the iliofemoral graft, and may result in possible failure of the operation; but this same process, by increasing the pressure, makes the ischiofemoral arthrodesis only more secure. In addition, progress of the disease will not interfere with ischiofemoral arthrodesis, as it does with iliofemoral arthrodesis, and further destruction of the head with increasing dead space will not place an added strain on the graft.

It is the purpose of this paper to report the writers' experiences with this method, and to describe minor modifications in technique which have been evolved. Since March 1943, nine patients at this Clinic have had arthrodeses by this method for tuberculosis of the hip, with a total of twelve hips operated upon, since three were cases of bilateral hip tuberculosis.

Indications

It is universally recognized that no one method of arthrodesis of the hip is applicable in all instances where this procedure is indicated. The choice of method will vary with the underlying disease process, its stage and exact extent, and with the patient's age and general condition.

The usual extra-articular, intra-articular, and "combined" arthrodeses of the hip often involve difficulty and considerable risk. This is especially true in elderly patients, and in patients with tuberculosis in which there is still some activity and in which there is considerable destruction of the hip and the ilium. The incidence of failure of arthrodesis in these latter cases is relatively high, and, if the full extent of progression of the process has not taken place, further destruction may jeopardize the result.

Although operation in an area of tuberculous disease does not necessarily result in failure, extra-articular arthrodesis is to be preferred, if there is a reasonable chance of success.

Ischiofemoral arthrodesis offers an alternative extra-articular method of obtaining a bony fusion between the femur and the pelvis. Trumble described a method by which this may be accomplished, but his procedure requires an extensive exposure in the gluteal region, with isolation of the sciatic nerve and insertion of a large tibial graft in a bed anterior to this nerve. This procedure requires adequate bony contact and soft-tissue fixation between the head and neck of the femur and the acetabulum.

Brittain's method of ischiofemoral arthrodesis can be employed in any condition in

which fusion of the hip is indicated. However, it is of particular value in cases of tuberculosis where the involvement is primarily acetabular, with upward extension into the ilium. Arthrodesis by the usual methods in such cases is difficult and frequently impossible, but with Brittain's method the graft is placed below the area of involvement. The tuberculous process rarely extends into the ischium, but if such a process were sufficiently advanced, it would, of course, be a contra-indication to the use of the Brittain method.

Due to the simplicity and ease with which the procedure may be accomplished, and to the absence of complications, it is possible by this method to arthrodese the hip in a patient in whom a more extensive procedure would otherwise be contra-indicated, because of age or general condition. This method is particularly useful in children with tuberculosis of the hip, for these patients are frequently in poor general condition. Major surgical procedures are, therefore, not indicated, even though the patients have been carefully prepared for surgery. In none of our cases was there postoperative shock, excessive hemorrhage, or nerve or visceral damage.

Since resubstitution of the graft is necessary before fusion can be complete, it is felt that the method is better suited to children than to adults, because the bone-regenerating and bone-revascularizing power in children is much greater than in adults. Consequently, it is only reasonable that arthrodesis, with an autogenous graft, should occur with greater rapidity in children. However, in Brittain's series, nineteen of his thirty-five patients were above the age of eighteen, his oldest patient being sixty-three years of age at the time of operation. In our series, eight of the nine patients were children whose ages varied from eight to thirteen. In the one adult, aged fifty-two, the graft became involved by the disease; thus a conclusion as to the length of time required for resubstitution of the graft in an adult could not be reached.

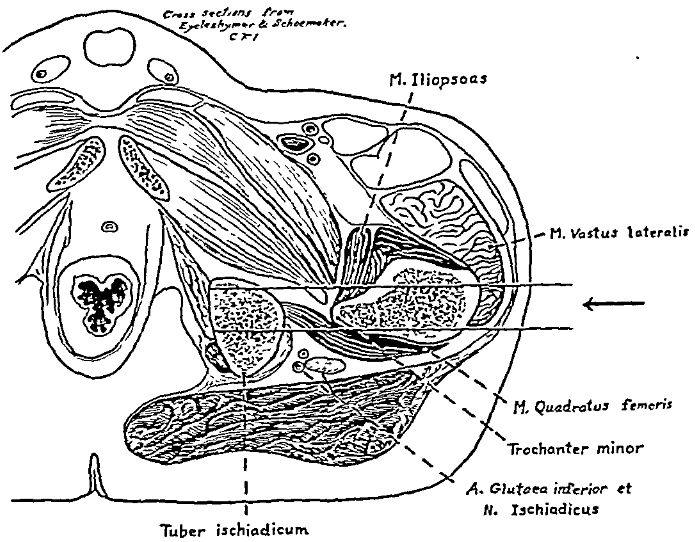

FIG. 1

Regional anatomy, showing path of osteotome and location of graft. (Composite cross-section from Eycleshymer and Schoemaker.[3] *Reproduced by permission from D. Appleton & Co.*)

Regional Anatomy

It might seem that this procedure would be hazardous, since it is done "blindly" through a lateral approach. However, roentgenographic control is used throughout, and a study of the regional anatomy reveals that the path through which the osteotomy is done and the graft inserted is quite safe, as long as all work is performed in the coronal plane (parallel with the table). Anteriorly, the femoral vessels are well forward, while posteriorly the sciatic nerve is safely out of the way. Medially, the adductor structures are not in the vicinity of the operative path (Fig. 1).

It might also appear that the graft could pass through the obturator foramen; but this, too, is an anatomical impossibility, because of the obliquity of the osteotomy in the one plane and the obliquity of the obturator foramen in the other plane. Penetration of the graft into the pelvis has not caused complications, and any penetrating portion is eventually absorbed (Figs. 2-B, 2-C, 4-B, and 4-C).

FIG. 2-A

J. M., female, aged thirteen. Tuberculosis of hip of eleven years' duration. Failure of fusion following iliofemoral arthrodesis.

FIG. 2-B

Immediate postoperative roentgenogram, showing position of graft and femoral fragments. Note intrusion of graft into pelvis.

FIG. 2-C

Result fourteen months after operation. Solid fusion has occurred, and patient now participates in normal activities without support. Note absorption of intrapelvic portion of graft, and adduction which occurred postoperatively.

THE METHOD

The patient is immobilized on the fracture table with a cassette holder under the hips, as for the insertion of a Smith-Petersen nail for a central fracture of the neck of the femur. A preoperative roentgenogram is made before the skin is prepared. A lateral longitudinal muscle-splitting incision is employed, extending down from the region of the abductor tubercle of the femur for a distance of three to five inches (7.5 to 12.5 centimeters). The shaft of the femur is exposed subperiosteally. A three-millimeter drill point is then drilled obliquely through the shaft of the femur at a predetermined level, utilizing the abductor tubercle as a localizing aid, and passing upward at an angle of 40 to 45 degrees with the shaft of the femur. The drill point is then removed, and a 1.5 millimeter guide wire (such as is used with the cannulated Smith-Petersen nail) is passed by hand through the drill hole in the shaft of the femur and on through the soft tissues in a plane parallel with the table, until the ischium is encountered. A Jacobs chuck drill is placed on the guide wire, which is then drilled into the ischium for 1.5 to two centimeters. A check-up anteroposterior roentgenogram is made to ascertain the position and the depth of the guide wire.

While this film is being developed, a full-thickness tibial graft is removed, including the anterolateral and posteromedial crests, the approximate length of the graft having been determined by measurements from the guide wire.

If alteration in placement of the guide wire is unnecessary, the femur is obliquely osteotomized alongside the guide wire, using a long, thin osteotome. The osteotome is then passed on into the ischium in the coronal plane. By a decreased sense of resistance, it is easy to determine, while driving the osteotome through the ischium, just when the medial cortex of the ischium is perforated. The guide wire is removed, and the osteotome is "rocked" up and down until an adequate cleft is made in the ischium. The handle of the osteotome is then depressed, and the graft, beveled on its presenting end, and with its medullary surface down, is inserted along the superior surface of the osteotome. The osteotome is withdrawn as the graft reaches the ischium, so that the graft can be driven into the prepared cleft. Next, the periosteum around the femur at the osteotomy site is completely severed, so that the distal fragment can be displaced medially. This is an essential step, since the periosteum is quite fibrous and tough in children, and, unless it is completely cut, medial displacement of the shaft of the femur is quite difficult. Medial displacement of the shaft is accomplished by traction, abduction, and direct pressure. When the displacement has been satisfactorily accomplished, the leg is placed in the position of choice, and

FIG 3

B. T., male, aged eight Both views of tibia thirteen months after removal of graft Note reformation of cortex

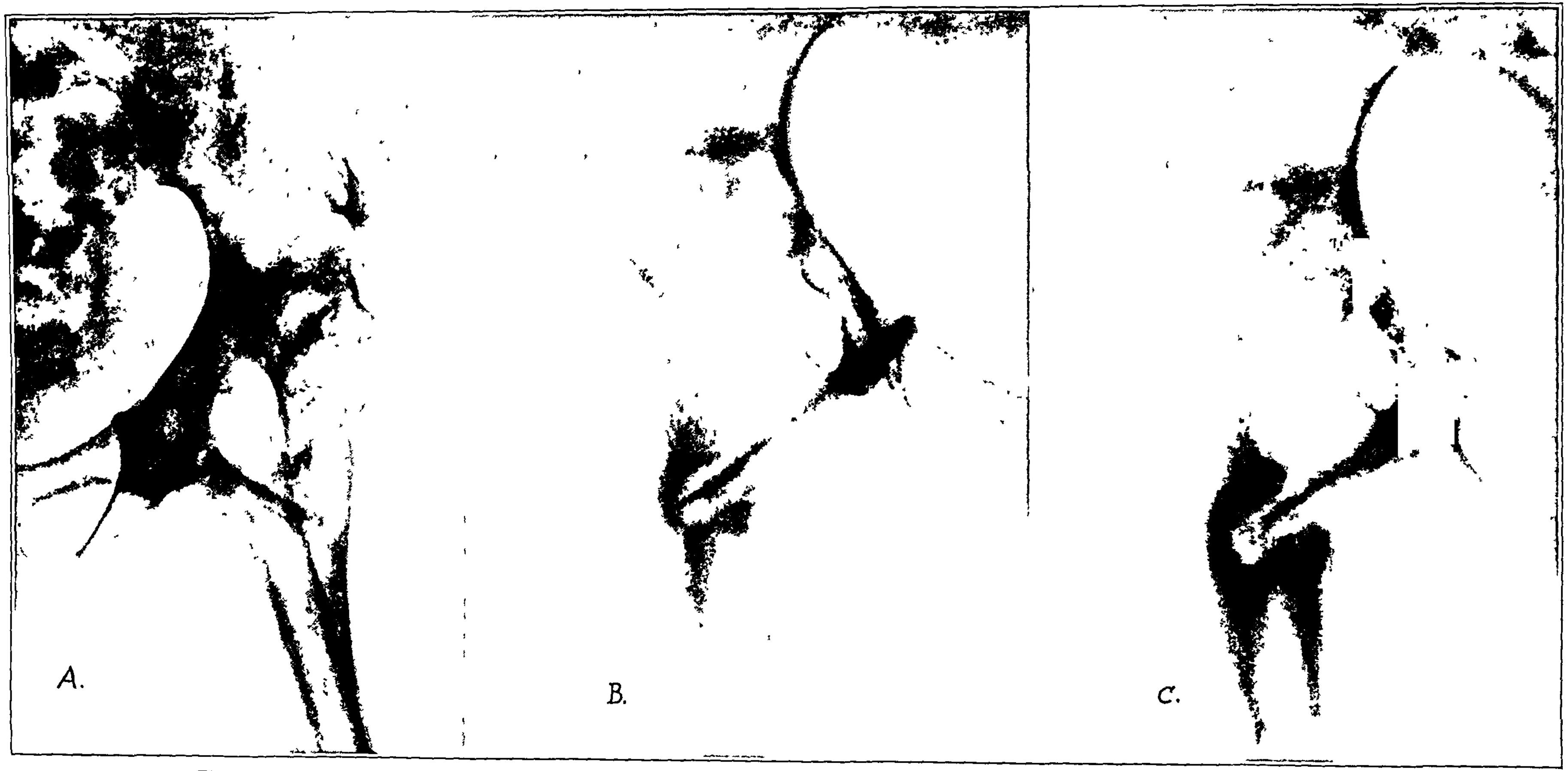

FIG. 4-A

M. D., female, aged eight. Bilateral tuberculosis of hip of five years' duration. Patient had had iliofemoral arthrodesis elsewhere, with failure. Fracture of graft occurred eight weeks after operation, while patient was being prepared for operation on opposite hip. This roentgenogram made eight months after fracture.

FIG. 4-B

K. M., male, aged eleven. Tuberculosis of hip of eight years' duration. Roentgenogram made four months after operation shows absorption about graft as result of inadequate immobilization. However, osteotomy has solidly united. Shaft inadequately displaced medially.

FIG. 4-C

Same patient as Fig. 4-B, ten months after operation. Note bony proliferation about lateral aspect of graft and absorption of the intrapelvic portion of graft.

final check-up roentgenograms are made. The wound is closed in a routine manner, and a full, double spica cast is applied, extending from the nipple line to the toes bilaterally in children, and to the knee on the opposite side in adults. If difficulty in maintaining the medial displacement of the shaft is encountered, the surgeon may apply the cast in sections, as suggested by Brittain,—that is, incorporating the leg up to the osteotomy site separately, and then completing the cast, after a satisfactory position of the fragments has been obtained. This method has the added advantage of preventing any valgus strain on the knee. In some instances, wide abduction of the leg may be necessary to maintain the displacement; in such cases, the cast may be changed after three weeks, and the leg brought into the optimum position without loss of medial displacement. Final check-up roentgenograms are made after the cast has been completed.

Fig 5-A

H. B., male, aged fifty-two. Tuberculosis of the hip of eight months' duration. Roentgenogram made two months after operation. The graft has become involved by the disease and sequestration is occurring.

RESULTS AND OBSERVATIONS

In this series of nine cases, with twelve hips arthrodesed, only seven cases (ten hips) can be considered, since two unilateral cases are too recent. There were no draining sinuses

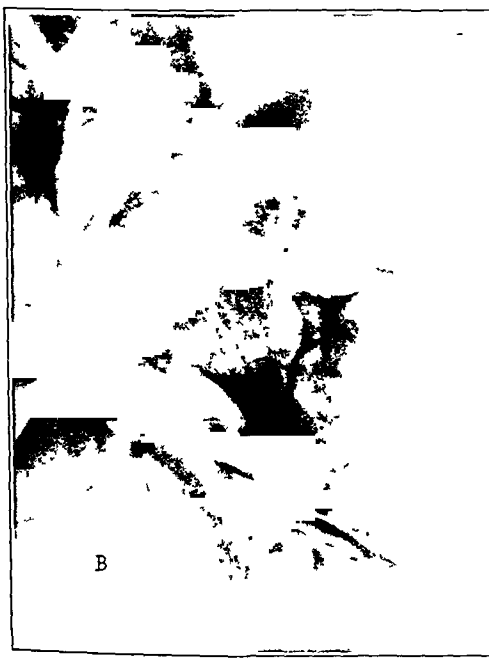

Fig 5-B

Appearance of hip nine months after operation. Note apparent progression of fusion despite sequestration of lateral portion of graft.

Fig 5-C

Roentgenogram seventeen months after operation. Further progress of fusion has taken place. Definite sequestration of lateral portion of graft has occurred. Note improvement in condition of head of the femur. Hip is clinically arthrodesed and the patient has been walking in a brace for six months.

Fig. 6
W. R., male, aged nine Bilateral tuberculosis of hip of six years' duration. Appearance thirteen months after last operation. Note variation in obliquity of grafts.

at the time of operation. Our follow-up period varies from eleven to twenty-three months; and of the ten hips, six are solidly arthrodesed clinically and roentgenographically.

At the present time, one hip shows sequestration of a portion of the graft (Figs. 5-A, 5-B, and 5-C), with involucrum formation about it, so that this result will undoubtedly also be successful. The infection was due primarily to the extension of the disease to the graft, with secondary infection after sinus formation.

Two of the grafts have fractured, and another graft shows absorption about the outer end. These complications will be discussed below.

In the present series, the following observations have been made:

1. *Obliquity of the Osteotomy and Graft*: The series is too small to determine the influence of obliquity of the graft on the outcome. However, it has been noted that an obliquely placed graft aids in medial displacement of the shaft of the femur (Figs. 2-A, 2-B, and 2-C). In fact, later roentgenograms may show further medial displacement of the shaft than was present immediately after operation.

2. *Size of the Graft*: Removal of such a large graft was at first done with some hesitancy, but the rapidity with which the tibia reformed in children has been most satisfying (Fig. 3). In one child there was a fracture of the donor leg, but, as stated above, in children the cast should incorporate the donor leg to guard against such a complication, as well as to increase the efficiency of the cast in immobilizing the hip. The fractures of the graft which occurred (Fig. 4-A) and the absorption about the outer end of the graft which occurred in one case (Figs. 4-B and 4-C) were the results of inadequate immobilization. At the present time, it appears that the arthrodesis in these cases may eventually succeed, if immobilization is continued for a sufficiently long period of time. If arthrodesis fails in these cases, there is no contra-indication to re-arthrodesis by the same method.

3. *Location of the Graft in the Ischium*: It must again be stressed that the cleft

in the ischium should be placed sufficiently low to avoid inserting the graft in a diseased area, with resulting involvement of the graft by the disease (Figs 5-A, 5-B, and 5-C).

4. *Displacement of the Shaft of the Femur*: Although in our earliest cases the importance of displacing the shaft of the femur adequately was not realized, calamities cannot be directly attributed to this. However, displacing the shaft medially adds to the stability of the arthrodesis, lessens the strain on the graft during fusion, and further ensures success, because of contact of the central portion of the graft with viable bone (Figs. 4-B and 4-C).

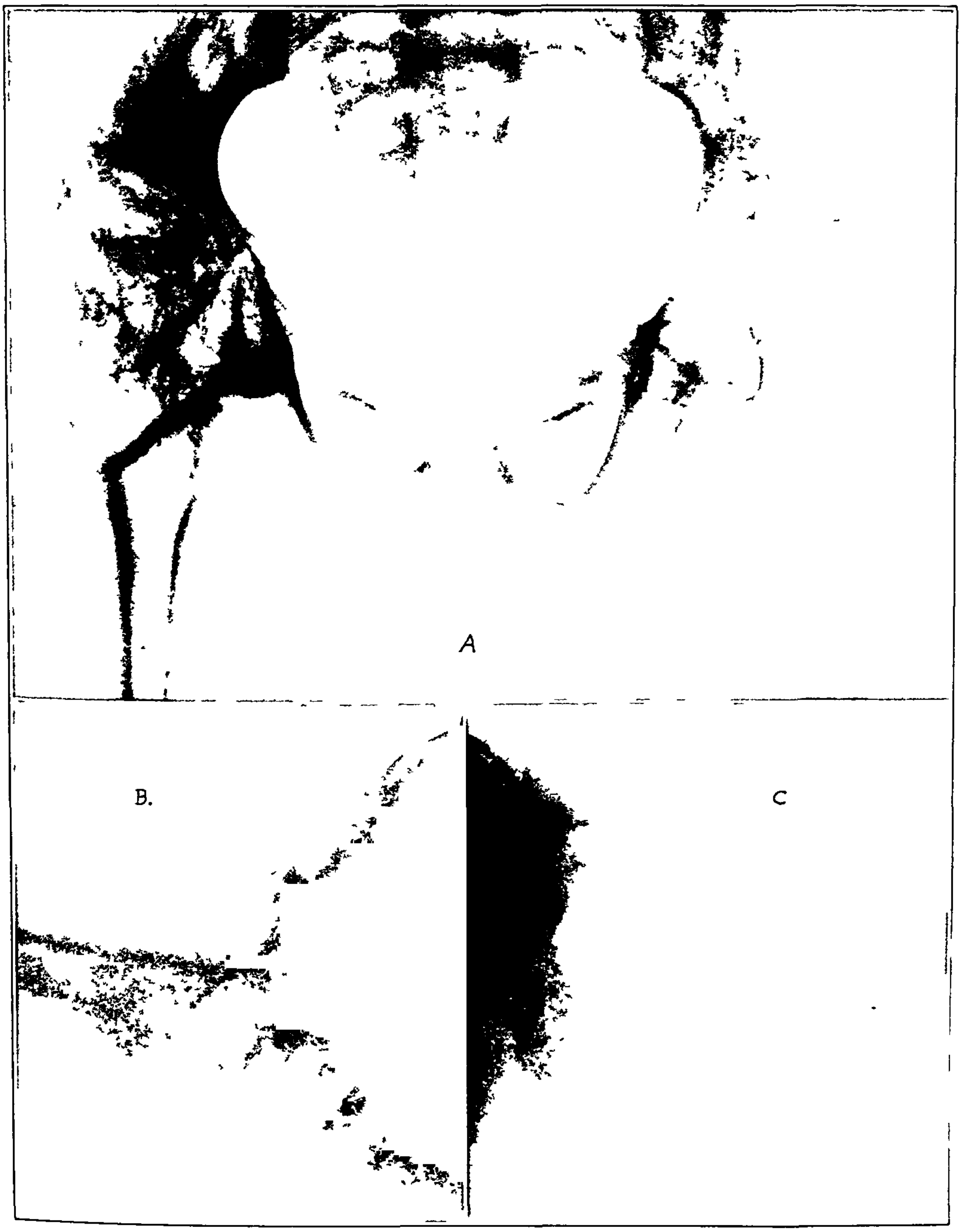

FIG 7

B T, male, aged eight Bilateral tuberculosis of hip of five years' duration *A*: Appearance thirteen months after last operation Weight-bearing has not been resumed *B* and *C* Lateral views of hips

5. *Position of the Hip*: In the one adult patient, the lower extremity was placed in the position of optimum function,—that is, 15 degrees of abduction, 20 degrees of flexion, and slight external rotation. In the remainder of the cases in children, the legs have been placed in abduction of 25 to 30 degrees, as adduction was anticipated with growth. However, in our cases, relatively little adduction from the original position has occurred as yet, although it is too early to determine to just what extent this will eventually take place. If necessary, a subtrochanteric osteotomy can be done at some later date to correct the weight-bearing alignment of this extremity.

6. *Bilateral Arthrodesis of the Hip*: This was done in three cases (Figs. 6 and 7). The healing of a tuberculous hip is accomplished only by arthrodesis or by excision. The latter is a formidable and mutilating procedure that is prohibited in most cases, whereas arthrodesis results in a stable hip with a minimum of deformity. Conservative attempts to maintain motion in one hip in cases of bilateral tuberculosis are dangerous and almost universally unsuccessful. Bilateral arthrodesis is to be preferred in such cases, despite the many disadvantages. This is especially true where financial considerations prevent prolonged hospital treatment, followed by many years of frequent and careful observation.

7. *Period of Immobilization*: In our cases, the site of arthrodesis has usually consolidated in from three to four months, but immobilization should be continued until the hip joint is solidly fused and the disease process is healed. As Brittain has stressed, this operation is only another method of enforcing rest for a tuberculous joint, and ambulation should not be allowed until healing of the disease itself is complete.

CONCLUSIONS

1. The Brittain ischiofemoral arthrodesis performed under complete roentgenographic control is simple, safe, extra-articular, and results in successful arthrodesis of the hip in a high percentage of cases.

2. Six of ten hips treated by this method and followed for a minimum of eleven months have fused. All of the failures can be attributed to errors in technique, rather than to failure of the method itself.

3. The Brittain method is especially applicable to children with tuberculosis of the hip, since consolidation of the osteotomy and revascularization of the graft occur rapidly, and the operation can be done in children who would not tolerate a more difficult and shocking procedure.

4. Our experience with this method in adults has not been sufficient to permit an opinion as to its value, although Brittain has successfully employed it in adults.

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ASEPTIC NECROSIS OF THE ASTRAGALUS FOLLOWING ARTHRODESING PROCEDURES OF THE TARSUS

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Aseptic necrosis of the body of the astragalus [talus] frequently occurs in major fractures and fracture-dislocations of this bone, because of the paucity of its blood supply. Several anatomical studies of the arterial circulation of the astragalus have recently been published. McKeever's is the most detailed. According to him, "the entire vascular supply of the astragalus is derived from branches of the anterior tibial artery. There is evidence also that the artery, which eventually breaks up into several nutrient arteries, is carried in the dense astragaloscaphoid ligament (ligamentum talonaviculare dorsale), which extends as a broad band from the dorsal surface of the neck of the astragalus to the dorsal periphery of the scaphoid. In this ligament the artery divides into several (two to four) smaller arteries which perforate the superomedial aspect of the neck of the astragalus, where foramina are clearly present. No evidence of arteries perforating from either the posterior or the anterior calcaneoastragalar ligament or from the internal calcaneo-astragalar ligaments in the subastragalar joint was apparent. In no instance was it possible to demonstrate arteries throughout the body of the astragalus."

Lipscomb and Ghormley describe the arteries to the astragalus as branches of the dorsalis pedis, entering the bone at the lateral aspect of the neck. According to them, a minor supply also enters through various smaller branches at the ligamentous and capsular attachments. Phemister, Sneed, and Watson-Jones differ on the finer details of the blood supply to the astragalus, but all agree on the precarious location of these vessels, an arrangement not dissimilar to that encountered about the head and neck of the femur.

It seems surprising, therefore, that aseptic necrosis of the astragalus has not been mentioned as a complication of arthrodesing procedures of the tarsus. It would appear inevitable after extensive resection of the head and neck of this bone. Our findings indicate that it occurs not too infrequently,—twice in one series of seventeen cases, and three times in another series of forty-four cases. No statistical significance can be ascribed to these figures, since the occurrence of aseptic necrosis depends on the extent of resection of the head and neck of the astragalus, and probably also on the extent of periosteal stripping at the operation. The latter factor is increased in re-operations, which as a rule require a more extensive exposure. In our group of five cases, two followed secondary arthrodesing procedures, and all involved extensive resection of the head and neck of the astragalus. Minor degrees of increased density and temporary mottling of the body of the astragalus were noted in several other cases. They did not persist long enough to warrant restriction of weight-bearing or immobilization beyond the usual period, and no harmful results ensued.

CASE REPORTS

CASE 1. A. A., a boy, aged fourteen, was admitted to the Mount Sinai Hospital for correction of a paralytic calcaneovalgus deformity of the left foot. On September 16, 1942, a reverse-type Lambrinudi procedure was performed. The peroneal muscles were transplanted into the os calcis. Extensive remodeling of the tarsal bones was necessary to correct the deformity, and the head of the astragalus was completely excised. The time required for operating was one hour and forty-five minutes. Following the operation, the patient was unable to move his toes, and had complete anaesthesia of the toes and of the distal foot. This was correctly ascribed to tourniquet paralysis, from which the boy recovered promptly. Later, superficial skin necrosis about the incision necessitated several changes of plaster, but this also healed readily. As early as three weeks after operation, the body of the astragalus was found to be denser than the surrounding bones upon roentgenographic examination (Fig. 1-A). This was interpreted as aseptic necrosis, and became more marked during the following months. No weight-bearing

FIG. 1-A

Case 1. Left foot three weeks after triple arthrodesis of reverse Lambrinudi type, with transplant of peroneals into os calcis for paralytic calcaneovalgus. Extensive resection of head and neck of astragalus, with suggestive increase of density in this bone.

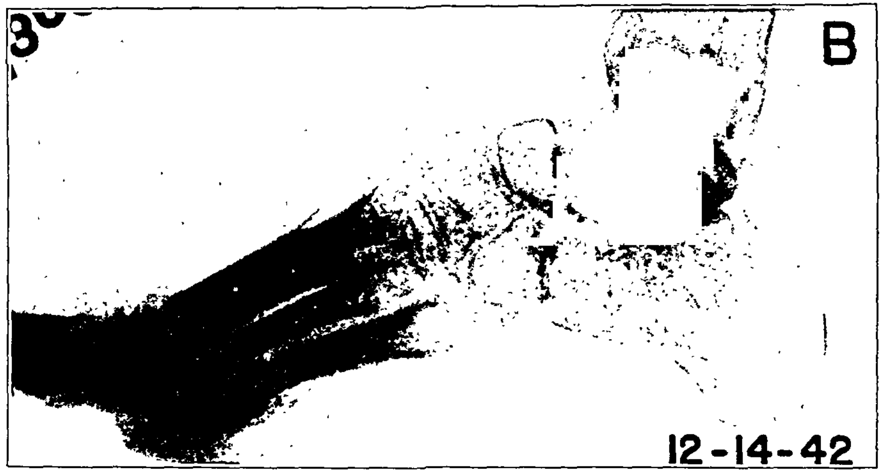

FIG. 1-B

Three months after operation, the astragalus was definitely the site of aseptic necrosis. Note marked relative density and mottling of astragalus in comparison with atrophy of remaining bones of foot.

FIG. 1-C

Five months after operation, there was good fusion and beginning revascularization.

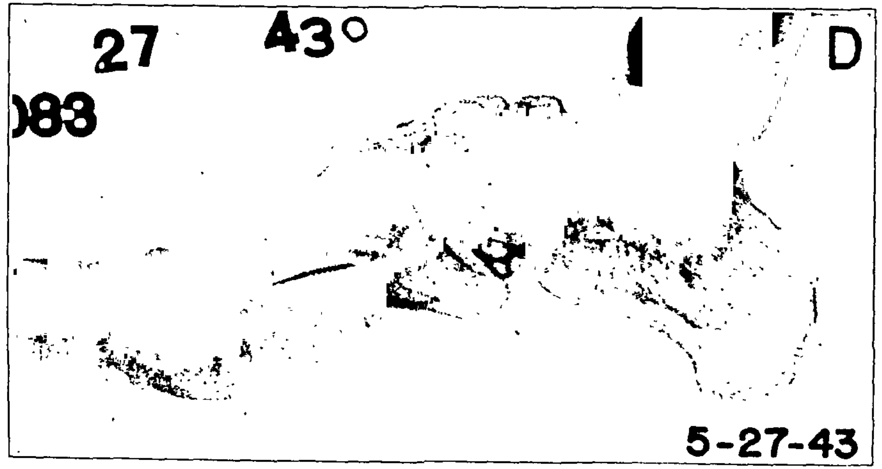

FIG. 1-D

Eight and a half months after operation, advanced revascularization had taken place. Weight-bearing without cast was begun.

was allowed until March 1943, approximately six months after operation, when considerable revascularization of the astragalus was noted. This boy was last seen eighteen months after operation, when the result of the procedure was judged excellent. The patient's gait was much improved, and he was able to walk long distances. The subastragalar and mid-tarsal joints were clinically fused in good position, with adequate backward displacement of the foot and good strength in the transplanted muscles. Roentgenographic examination at this time showed solid bony union of the arthrodesed joints. The astragalus was completely revascularized. There was no deformity of the remaining body, and no evidence of irregularity of the surface of the ankle joint.

CASE 2. C. O., a woman, aged forty-eight, was admitted to the Mount Sinai Hospital for correction of a paralytic equinovalgus deformity of the left foot. A modified Lambrinudi procedure was performed on June 18, 1938. The head and neck of the astragalus were completely resected. Because of persistent

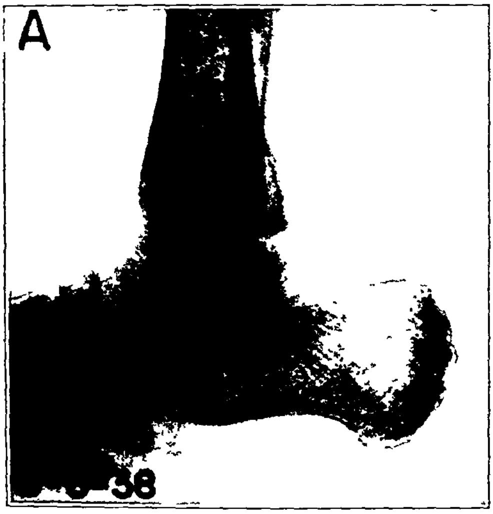

FIG. 2-A

Case 2. Left foot two and a half months after operation. Modified Lambrinudi type subastragalar arthrodesis was performed for paralytic equinovalgus, with extensive resection of head and neck of astragalus (the calcaneocuboid joint was spared).

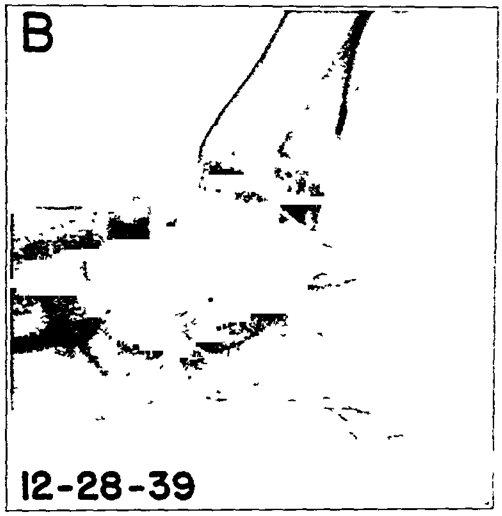

FIG. 2-B

Eighteen months after operation. A secondary mid-tarsal arthrodesis had been done nine months postoperatively. Note diminution of height of astragalus and relative density of this bone.

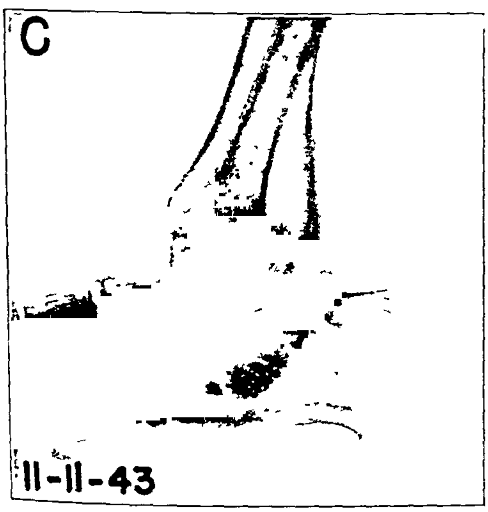

FIG. 2-C

Showing further collapse and compression of astragalus at the site of aseptic necrosis. There was incongruity of the tibial and astragalar articular surfaces in the ankle joint.

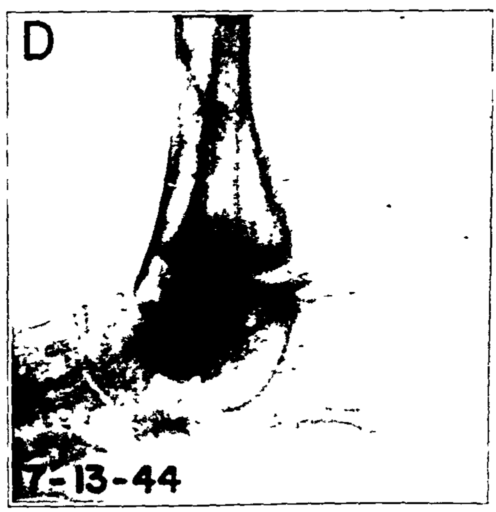

FIG. 2-D

Six months after ankle fusion, which was necessitated by pain and arthritis in ankle joint.

Fig. 3-A

Case 3. September 7, 1943. Right foot twelve years after posterior subastragalar fusion had been performed with a Campbell bone block for paralytic drop-foot. The mid-tarsal joint was intact.

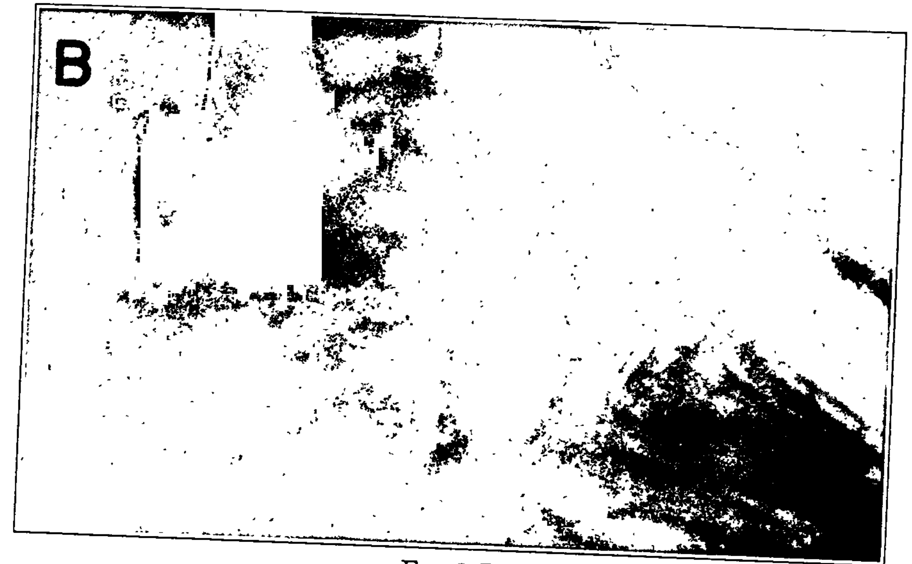

Fig. 3-B

October 26, 1943. Roentgenogram taken immediately after triple arthrodesis (Ryerson type) for paralytic equinovarus, with extensive resection of head of astragalus.

Fig. 3-C

Three months after operation, showing diffuse mottling and relatively greater density of remaining astragalus, with decrease in height of bone.

Fig. 3-D

Six months after operation. Patient is ambulatory, and weight-bearing has been permitted for three months since removal of plaster. Showing increased density and collapse of astragalus

pain related to the mid-tarsal joint, a secondary wedge resection of this joint was necessary. This was done on March 18, 1939, nine months after the first operation. Weight-bearing was allowed four months later. No attention was paid to the avascular necrosis of the body of the astragalus, which had occurred following the second operation. This bone went on to progressive collapse under unprotected weight-bearing. A severe degenerative arthritis of the ankle developed with marked disability and pain. Despite various conservative measures, including bracing, arthrodesis of this joint had to be undertaken. The ankle fusion was done on January 22, 1944, utilizing a bone graft from the tibia in addition to the usual intra-articular technique. Solid bony ankylosis was accomplished in eight months. When last seen, thirteen months after ankle fusion, the patient's gait was much improved. There was minimal residual pain, and the patient was ready to return to light work.

CASE 3. R. W., a man, aged twenty-eight, was admitted to Bellevue Hospital for correction of a severe equinovarus deformity of the right foot. In 1931 a posterior subastragalar arthrodesis with a Campbell bone block had been done for paralytic equinus, which was the result of severance of the peroneal nerve at the neck of the fibula, in an operation for osteomyelitis of that bone. This operation for the drop-foot was only partially successful. On October 25, 1943, an external T-shaped wedge was removed to correct the deformity. The subastragalar joint was found partly fused, and it was revised. The mid-tarsal joint was also arthrodesed. Weight-bearing in plaster was allowed six weeks after the operation, despite the aseptic necrosis of the astragalus which was noted in retrospect. This bone collapsed, and thus was initiated a severe arthritis of the ankle. When last seen eight months after operation, the patient complained of persistent pain in the foot and ankle.

FIG. 4-A

Case 4. June 5, 1941. Preoperative roentgenogram, showing paralytic or congenital varocavus deformity of right foot.

FIG. 4-B

September 5, 1941. Two months after triple arthrodesis (Ryerson type) with large dorsal wedge, including entire head and neck of astragalus.

FIG 4-C

FIG. 4-C

February 2, 1942. Seven months postoperative. Early revascularization of necrotic astragalus. No weight-bearing had been allowed because of later operation on left foot.

FIG. 5-A
Case 5. August 20, 1940. Preoperative roentgenogram of right foot, showing marked fixed paralytic equinovarus.

FIG. 5-B
September 17, 1940. One month after panastragalar arthrodesis, showing small size, increased density, and mottling of astragalus.

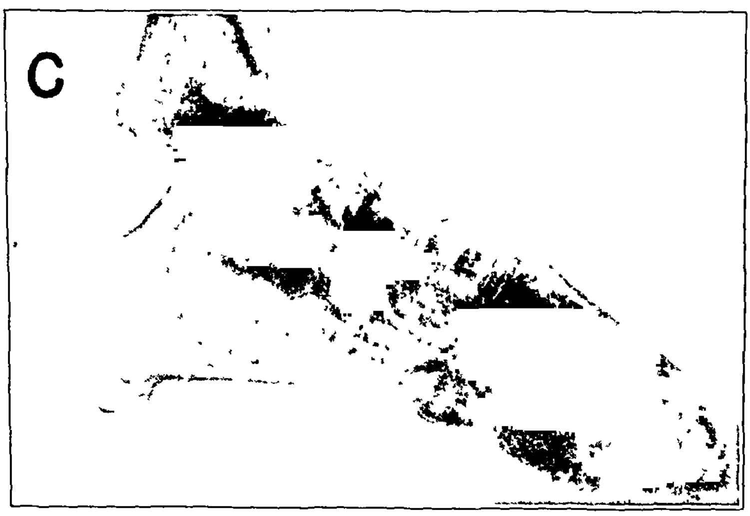

FIG. 5-C
March 12, 1941. Seven months after operation. Note further collapse and increased density of astragalus. Fusion of all joints was solid. Clinical result is probably satisfactory.

We have been unable to reach him for further study, but it is likely that painful symptoms will continue until ankle fusion is done.

CASE 4. W. W., a boy, aged thirteen, was admitted to Bellevue Hospital for extreme cavus deformity of the foot, probably congenital in nature. On July 7, 1941, the right foot was operated upon. A triple arthrodesis was done, and the entire head and neck of the astragalus were resected. To ensure adequate plantar flexion of the heel, double Kirschner-wire fixation in heel and tibia was used. A plantar fasciotomy had to performed. Good correction of the cavus was obtained, but avascular necrosis of the astragalus followed. Fortunately, because of a similar procedure on the left foot on October 6, 1941, the patient was not permitted to walk until six months after the first operation. By this time the astragalus of the right foot was well revascularized. (Incidentally this complication did not follow operation on the left foot in spite of a similar procedure.) When last seen, seven months after the last operation, the patient had no pain, and his gait was good.

It has been impossible to obtain any further follow-up. It is unlikely that this boy will have any difficulty with his ankle.

CASE 5. J. A., a woman, aged forty, was admitted to Bellevue Hospital for correction of a paralytic equinovarus deformity of the right foot. All muscles below the knee were paralyzed. The heel cord was contracted, permitting only 15 degrees of passive motion in the ankle. On August 21, 1940, a panastragalar arthrodesis was performed. No late follow-up is available, but roentgenograms approximately seven months after operation showed satisfactory fusion, despite aseptic necrosis and partial collapse of the remaining portion of the astragalus.

The next case is briefly mentioned for comparison of the rate of revascularization of an aseptically necrotic astragalus resulting from fracture.

CASE 6. A. V., a boy, aged fourteen, had fallen down a six-story elevator shaft one hour before admission to the Mount Sinai Hospital. Among other severe injuries he had sustained a severely com-

pounded comminuted fracture of the right tibia and fibula just above the ankle, and a slightly displaced fracture of the neck of the astragalus When first seen he was in severe shock, which was given first consideration. Only a superficial débridement of the compound fracture was done, and gas gangrene later developed, necessitating wide drainage. The leg was saved, but during the critical period, reduction of the astragalus had to be neglected. The fracture healed, despite aseptic necrosis of the body of the astragalus. Roentgenographic study six and one half months after injury showed advanced revascularization, without ankle deformity. This boy has not been permitted to bear weight up to the present time, eight months after the fracture.

DISCUSSION

It is often necessary to resect the head of the astragalus to correct marked deformity of the foot If extensive excision is unavoidable, it would appear advisable to remove additional bone from the scaphoid [navicular] or the cuneiform, rather than from the astragalus In any case, the postoperative roentgenograms should be carefully inspected to discover possible aseptic necrosis of the astragalus. In the event of this complication, weight-bearing must be avoided. If unrestricted weight-bearing is allowed on a necrotic astragalus before revascularization takes place, this bone will collapse in whole or in part. The ankle-joint surface of the astragalus will become irregular, and lead to disturbance of the ankle joint with resulting osteo-arthritis; this may require arthrodesis for relief of pain and disability. In other words, the principle of safeguarding necrotic bone from weight-bearing until it has become revascularized must be strictly observed. As Phemister has expressed it: "Function hastens to some extent the rate and increases the extent of repair. It should,

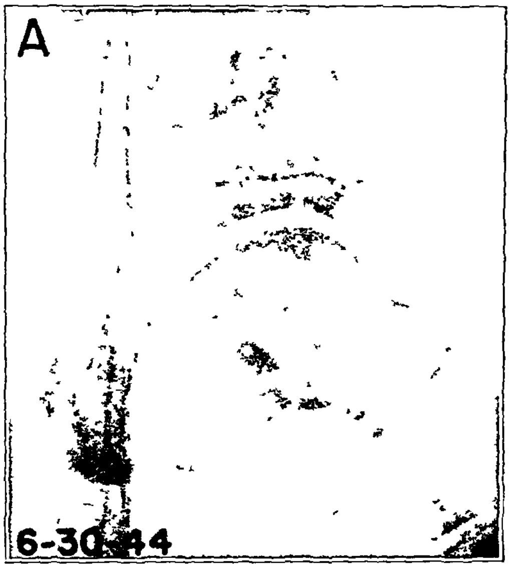

Fig 6-A

Case 6 Fracture of the neck of the right astragalus

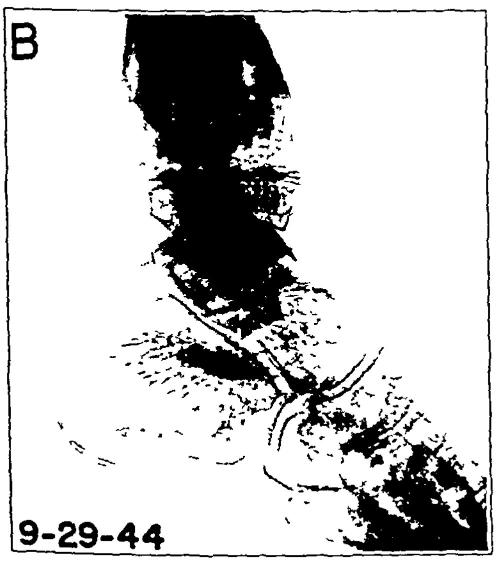

Fig 6-B

Three months later, aseptic necrosis of the body of the astragalus was clearly shown by increased density of this part of the bone No weight-bearing had been allowed

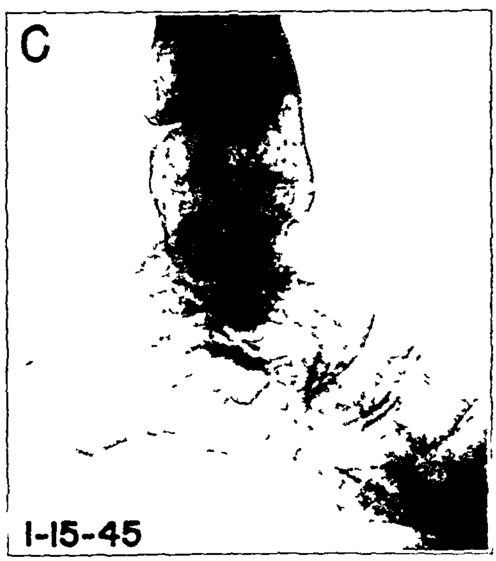

Fig 6-C

Six and a half months after fracture, showing considerable revascularization

however, be limited well within the strength of the necrotic bone and of the newly forming bone during the major part of the period of creeping substitution. If, in case of necrosis of the ends of the bones, there is too much weight-bearing, strain, or trauma in any form, there will be fracture of the necrotic bone or of the weak new bone . . ." While we have no large experience, revascularization of a necrotic astragalus appears to require about six to nine months in the average adolescent.

Where aseptic necrosis occurs in the presence of an ankle fusion, done as part of the primary procedure (panastragalar arthrodesis), the clinical significance of the lesion is much less, provided fusion of the ankle is successful. This may be delayed, because of the aseptic necrosis of the bone at the site of fusion, though revascularization in such an area is quite rapid.

CONCLUSIONS

1. Aseptic necrosis of the body of the astragalus is a not infrequent complication following arthrodesing procedures, requiring extensive resection of the head and neck of the astragalus, in order to correct severe deformities of the foot.
2. The frequency of this complication is sufficient to suggest that, when wide wedges are essential, the scaphoid should be sacrificed in preference to the astragalar neck.
3. Aseptic necrosis, if present, may be detected by roentgenographic examination as early as three to four weeks after operation. Suitable precautions should then be instituted.
4. Revascularization in the average adolescent takes place quite rapidly (six to nine months). Collapse of the body of the astragalus may be prevented by not permitting weight-bearing until this has been accomplished.
5. If premature weight-bearing is allowed, the body of the astragalus will become compressed, and the ankle-joint surface damaged, resulting in secondary osteo-arthritis of the ankle joint. This may require subsequent fusion for relief of pain and disability.
6. If ankle fusion is part of the primary procedure, aseptic necrosis of the astragalus is not as serious a complication.

NOTE: The authors wish to express their appreciation to Arthur Krida, M.D., for permission to use Cases 3, 4, and 5 from his Service at Bellevue Hospital.

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DIFFICULT FRACTURES OF THE NECK OF THE FEMUR TREATED WITH THE STUD-BOLT SCREW

Simplification of Technique

BY F. E. GODOY-MOREIRA, M.D., SÃO PAULO, BRAZIL
Professor of Orthopaedic Surgery, University of São Paulo, Brazil

In this paper the author wishes to present his results in the use of the stud-bolt screw for the treatment of ununited fractures or otherwise difficult cases of fracture of the neck of the femur.

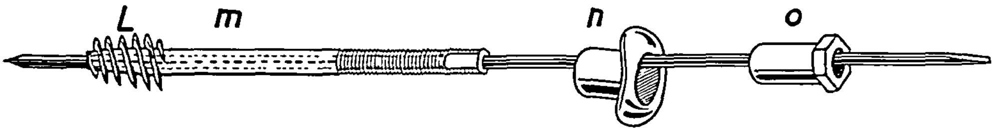

Fig. 1-A

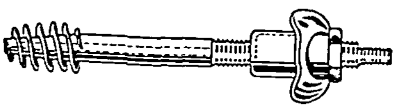

Fig. 1-B

Fig. 1-A: The parts of the screw are shown: *m*, the body; *n*, the flange; *o*, the nut. The helical thread *l* is very thin and penetrates the bone easily. This prevents turning of the head of the femur when the screw is driven home. The nut *o* is longer than the flange *n*; thus, when the nut is tightened, friction takes place only at the bottom and not at the top of the flange.

Fig. 1-B: The screw assembled.

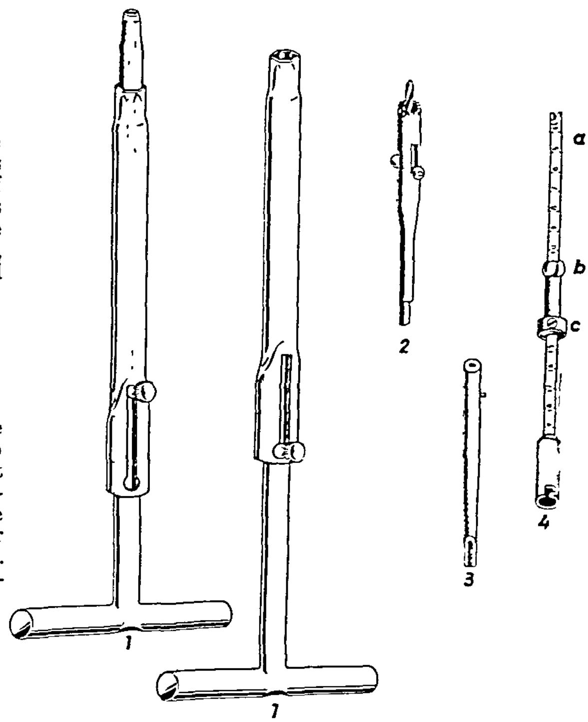

Fig. 2

Fig. 2

1: Double-action wrench; *2*: Trephine with guiding center pin; *3*: Attachment to receive the Kirschner wire and to prevent it from being pushed into the pelvis; *4*: Combined drill: *a* has the same diameter as the body of the screw (Fig. 1, *m*); *b* shows burr with the same diameter as the flange (Fig. 1, *n*); *c* is the collar which limits the penetration of the drill to the desired depth.

Since the publication of the writer's earlier article on this subject in *The Journal of Bone and Joint Surgery* in July 1940, we have operated upon eighty patients, using this technique, and the results have been excellent. Breaking or slipping of the screw has not been observed in any case.

The criterion in the classification of end results varies so widely that statistics in this particular instance are not always to be relied upon. The best way of demonstrating the quality of the results would be the reproduction of all of the roentgenograms, but the space required would make it difficult for our large series of cases to be presented. It would seem that the demonstration of a small number of difficult cases, in which good union and good function have been obtained, is more apt to prove the efficacy of the method than

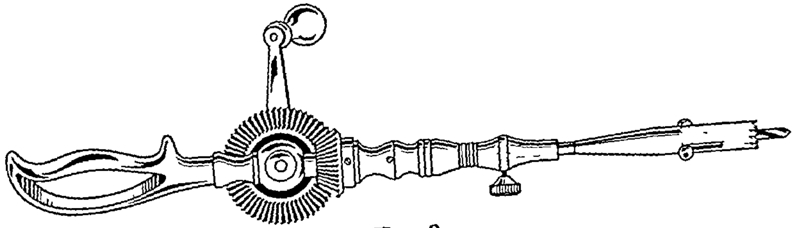

Fig. 3
Trephine attached to ordinary bone drill.

Fig. 4
(See below)

Removal of a circular piece of the cortex using the special trephine. The diameter (t) is the same as that of the flange (Fig. 1,n). The movable piece (r) permits ejection of the fragment of bone which remains inside the trephine.

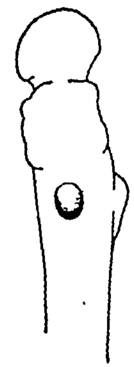

Fig. 5
Hole in the cortex made by the trephine.

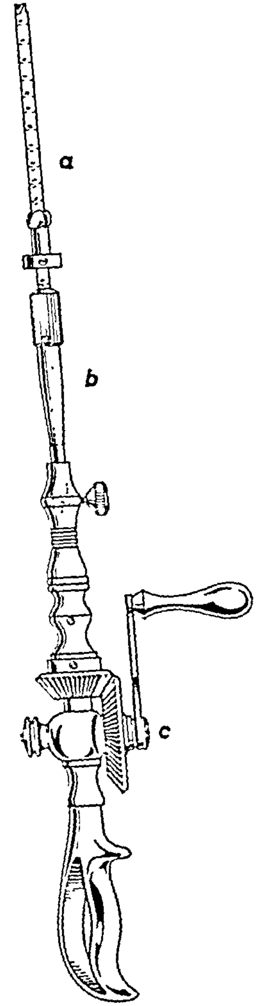

Fig. 7
The drill (a), attachment (b), and ordinary bone drill (c).

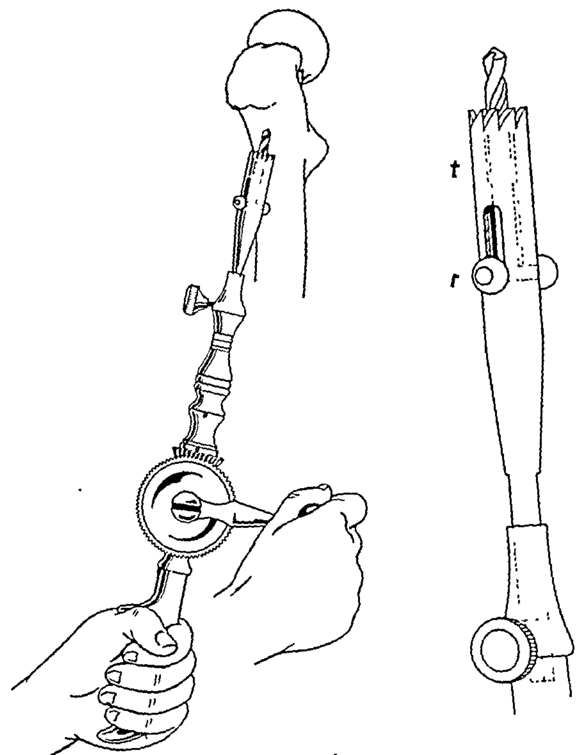

Fig. 4

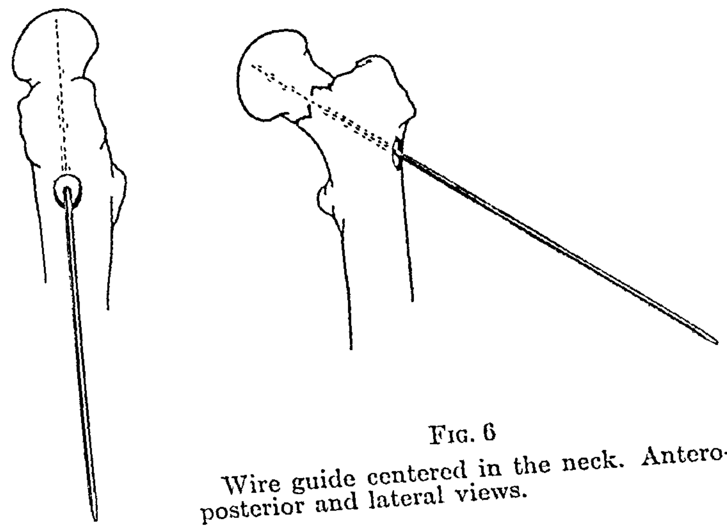

Fig. 6
Wire guide centered in the neck. Anteroposterior and lateral views.

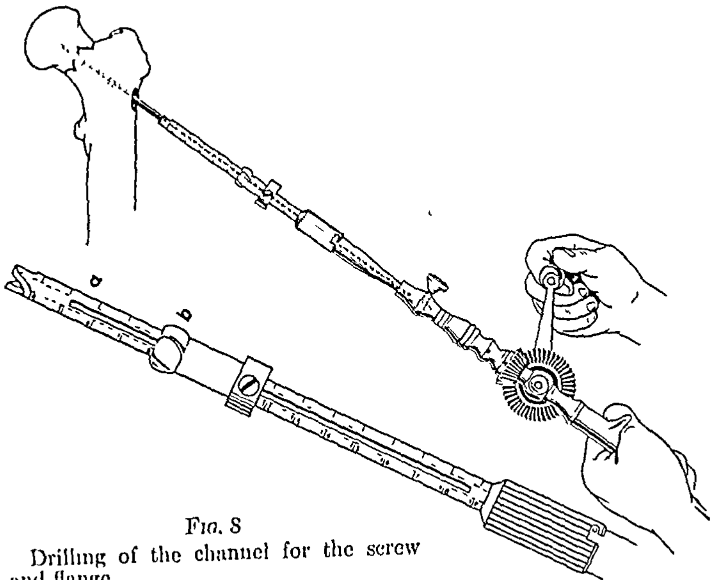

Fig. 8
Drilling of the channel for the screw and flange.

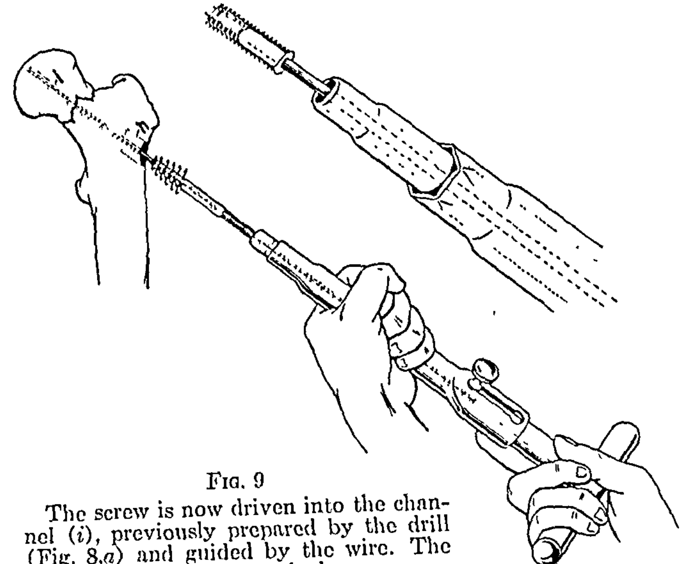

Fig. 9
The screw is now driven into the channel (*i*), previously prepared by the drill (Fig. 8,*a*) and guided by the wire. The wrench is turned, not pushed.

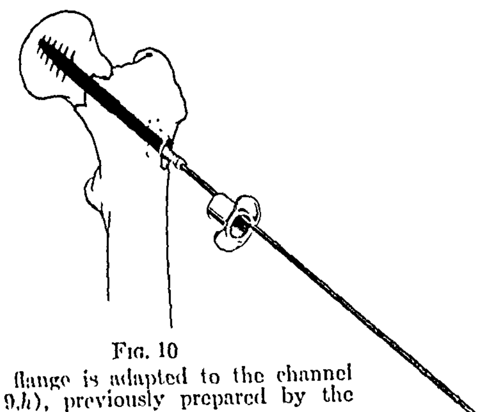

Fig. 10
The flange is adapted to the channel (Fig. 9,*h*), previously prepared by the burr (Fig. 8,*b*).

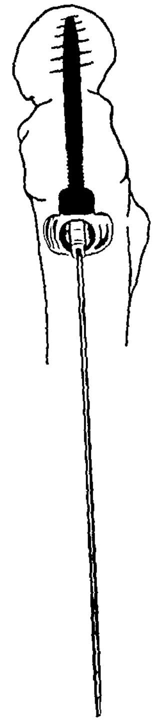

Fig. 11
Lateral view of the flange inserted.

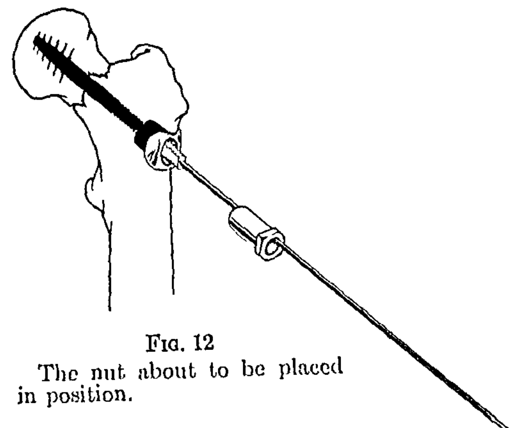

Fig. 12
The nut about to be placed in position.

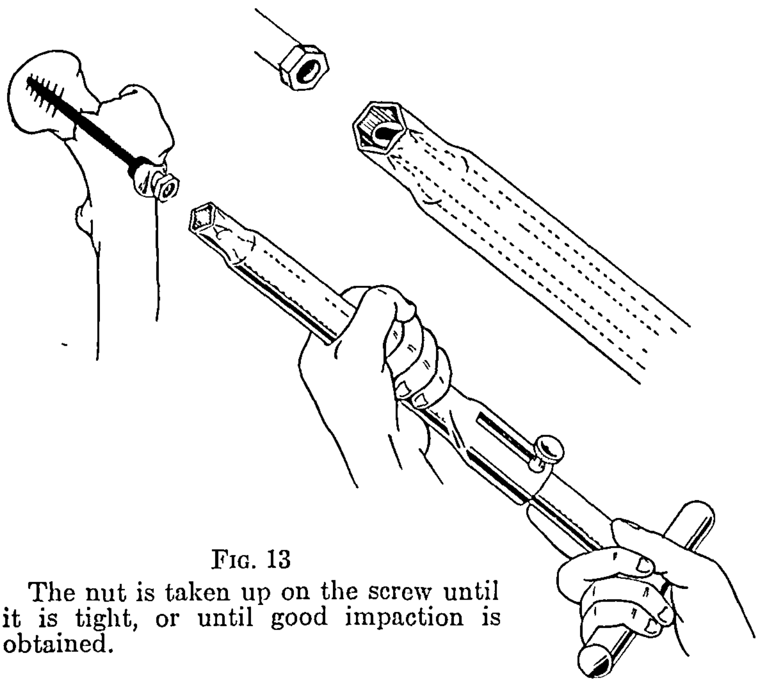

FIG. 13
The nut is taken up on the screw until it is tight, or until good impaction is obtained.

would be the presentation of greater number of more commo cases.

OPERATIVE TECHNIQUE

The writer's earlier tech nique has been considerabl modified, so that the method nov employed is one of the most sim ple of all techniques using screws and it requires fewer special in struments. The electric moto was used in approximatel twenty operations, and presente several disadvantages,—such a complexity and motor failures Therefore, it seemed that an or dinary hand-driven bone dril would be more satisfactory.

The perforation of the hard cortex with the hand-driven burr is difficult, but, onc the spongy bone has been reached, the procedure goes smoothly. Norman Roberts an Watson-Jones gouge a hole in the cortex beforehand, and we have devised a trephine fo the same purpose. With the spongy bone exposed, the hand-driven bone drill works s easily that a motor can be dispensed with.

The drawings clearly illustrate the simplicity of the technique and instruments nov in use.

CASE REPORTS

From a series of eighty operations, a small number of particularly difficult cases ar submitted, in which union and perfect function have been obtained.

CASE 1. A. S. B., female, fifty-two years old, was first seen on April 4, 1941. Four months previousl she had suffered a fracture of the neck of the left femur. Treatment had not been administered, and sh was bedridden at the time of consultation.

Roentgenogram (Fig. 14-A) showed non-union of the unreduced fracture. Operation, using th technique illustrated, was performed on April 5, 1941. Plaster cast was not applied. Walking was begu on the thirtieth day after the operation. Frontal and axial roentgenograms (Figs. 14-B and 14-C) eleve months after the operation showed good union. Walking is normal.

CASE 2. J. B., Jr., male, forty-three years old, was seen on August 19, 1941. Three months previ ously the patient had suffered a fracture of the neck of the right femur. Traction had been applied fo

FIG. 14-A
Case 1. April 4, 1941.

FIG. 14-B
March 10, 1942.

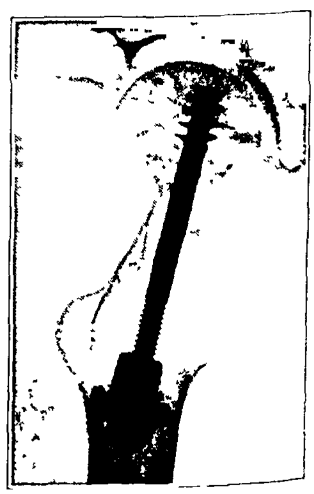

FIG. 14-C
March 10, 1942.


Fig. 15-A
Case 2. August 20, 1941.


Fig. 15-B
October 7, 1943.


Fig. 15-C
October 7, 1943.


Fig. 16-A
Case 3. September 23, 1941.


Fig. 16-B
March 27, 1944.


Fig. 16-C
March 27, 1944.

fifty days. The patient complained of pain and inability to walk without crutches. Roentgenogram (Fig. 15-A) shows the unreduced fracture in varus. Operation was performed on September 2, 1941. Cast was not applied. The patient began to walk on the fortieth day after operation. Roentgenograms (Figs. 15-B and 15-C) two years after the operation showed perfect union. Function of the leg is normal.

Case 3. M. R., female, fifty years old, was first seen on September 23, 1941 (Fig. 16-A). The patient had fractured the neck of the left femur three months previously. Treatment consisted only of bed rest. Walking was impossible, and the patient complained of pain. Traction was applied for a week, and operation was then performed. Plaster cast was not applied. Walking was begun fifty days after the operation, having been somewhat delayed because of pain in the knee.

Roentgenograms (Figs. 16-B and 16-C) taken two and a half years after the operation, on March 27, 1944, showed bony union. Function of the leg was completely normal.


Fig. 17-A
Case 4. July 2, 1941.


Fig. 17-B
August 31, 1943.

Case 4. L. A. T., male, forty years old, was seen on July 2, 1941. Nine months previously the patient had fractured the neck of the right femur. Conservative treatment was

unsuccessful, and the patient was walking with the aid of crutches when first seen. Roentgenogram (Fig. 17-A) showed non-union with marked resorption of the neck. Operation was performed on July 4, 1941. At the same time, a subtrochanteric osteotomy was done, because the writer feels that in cases of non-union of long duration the association of osteotomy and osteosynthesis is useful. After twenty days, plaster was applied down to the knee, leaving the knee free. The cast was left on for thirty days. Walking was begun on the twenty-first day after the operation.

Roentgenogram (Fig. 17-B) made two years after the operation showed union. Walking was normal. A shortening of 2.5 centimeters could be compensated for by the shoe.

Fig. 18-A
Case 5. April 29, 1940.

Fig. 18-B
January 21, 1941.

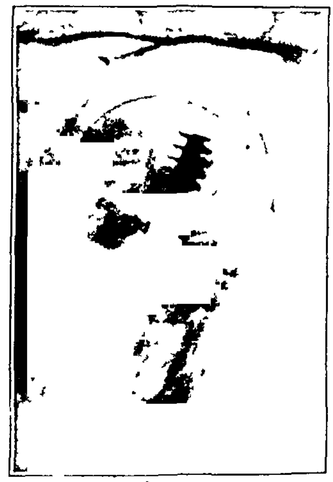

Fig. 18-C
January 21, 1941.

Case 5. A. A., male, seventy years old, was seen on April 29, 1940. Eighteen months previously, the patient had fallen from a ladder, and had since been unable to use his left leg. The only treatment was bed rest for two months, and then the patient had begun to walk with two crutches, continuing to use them up to the date of consultation. Roentgenogram (Fig. 18-A) showed pseudarthrosis with extensive resorption of the femoral neck.

Operation was performed on May 3, 1940. Plaster was applied down to the knee twenty days after the operation, and walking was then begun. The plaster was removed after forty days, and walking was continued with a cane. Eight and a half months after the operation, the patient was able to walk two miles easily. Roentgenograms (Figs. 18-B and 18-C) showed that non-union persisted, but the head remained firmly pressed against the trochanter.

This shows that, even when bony union does not take place, the osteosynthesis by means of the screw is solid enough in some cases to permit good function, the weight-bearing being supported mainly by the screw.

Fig. 19-A
Case 6. December 4, 1943.

Fig. 19-B
March 13, 1945.

Case 6. A. R., male, sixty-one years old, was seen on December 4, 1943. One year and four months previously, the patient had fractured the neck of the right femur. He was treated by traction for forty days, and was walking with two crutches. Roentgenogram (Fig. 19-A) made on December 4, 1943, showed non-union. Operation was performed on December 13, 1943.

Owing to the long duration of the pseudarthrosis, it was decided to perform a subtrochanteric osteotomy at the same time as osteosynthesis. The osteotomy, which immediately followed the osteosynthesis, was intended to increase the circulation of blood, and no attempt was made to displace the distal fragment inward under the weight-bearing line. A short plaster cast was applied, and walking was begun on the twentieth day. The cast remained on for forty days, and then walking with a cane was continued. Roentgenogram (Fig. 19-B), made on March 13, 1945, fifteen months after the operation,

showed complete union. The patient is now working on a farm, and feels no difference in the function of his legs.

CASE 7. F. A., male, sixty years old, was first seen on July 29, 1944. The patient, for many years a diabetic, had fractured the neck of the left femur sixty-nine days previously. He had been treated by traction, and was unable to stand without crutches. Roentgenogram (Fig. 20-A) showed lack of union.

Operation was performed on August 1, 1944. The patient began to walk twenty days afterward in a short plaster spica. Plaster was removed after forty days. The patient is now able to walk perfectly well all day long. Roentgenograms (Figs. 20-B and 20-C), made on March 11, 1945, seven and a half months after the operation, showed union.

FIG. 20-A
Case 7. May 21, 1944.

FIG. 20-B
March 9, 1945.

FIG. 20-C
March 9, 1945.

CASE 8. M. J. S., female, sixty-five years old, was seen on February 26, 1944. Two days previously the patient had suffered a fracture of the neck of the left femur (Fig. 21-A). Operation was performed on February 27, 1944. Four months after the operation, roentgenograms (Figs. 21-B and 21-C) showed perfect union, and walking was normal.

This case is presented to show that, even if the centering of the screw is unsatisfactory, provided impaction is possible, a solid and quick union may be obtained. In the present case, we were forced to accept the first and very imperfect centering of the wire because the patient was not tolerating the anaesthetic well. The screw was placed too far posteriorly distally. Nevertheless a good functional result was obtained.

SUMMARY

1. A series of end results of the treatment with the stud-bolt screw of some particularly unfavorable cases of fracture of the neck of the femur is presented.

FIG. 21-A
Case 8. February 26, 1944.

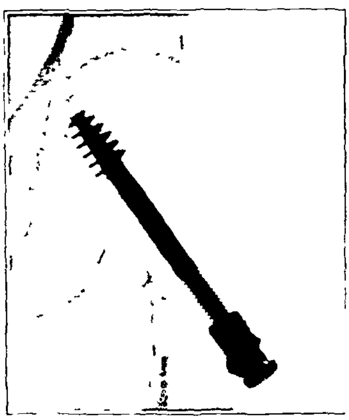

FIG. 21-B
June 20, 1944.

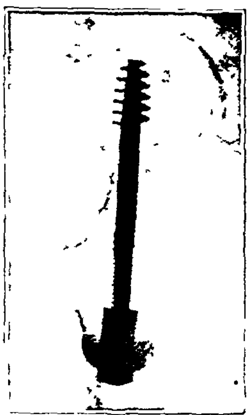

FIG. 21-C
June 20, 1944.

2. The technique and the instruments for the osteosynthesis have been greatly simplified since the author's first description.

3. A hand drill is used instead of the electric motor, and very few special instruments are required, thus making the operation practicable for more surgeons.

4. Eight cases, selected from a series of eighty operations, are reported to demonstrate that, even under particularly unfavorable conditions, union and good function may be obtained with the stud-bolt screw.

5. Two cases of non-union, one of nine and one of sixteen months' duration, are reported, in which union and perfect function have been obtained by the association of osteosynthesis and osteotomy in the same operation.

6. The good results in these difficult cases are attributed to the solidity of the osteosynthesis, and to the strong impaction produced by the stud-bolt screw.

7. A short plaster cast, leaving the knee free, is now usually applied about twenty days after the operation, when the patient begins to walk. This is removed after forty days.

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SELECTION OF CASES FOR ARTHROTOMY OF THE KNEE IN AN OVERSEAS GENERAL HOSPITAL

A Two-Year Follow-up Study

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This report represents a follow-up study of patients operated upon, for internal derangement of the knee joint, who were returned to duty from a General Hospital in the Southwest Pacific Area over a two-year period, from July 1942 to July 1944.

Three means of obtaining accurate follow-up information were available:

First, in order to determine whether any of our patients had been rehospitalized, a follow-up questionnaire, requesting diagnosis, treatment, and disposition, was sent to every General Hospital, Station Hospital, and Evacuation Hospital in the Southwest Pacific Area.

The second means of follow-up was available through the office of the Base Registrar for patients who may have been assigned to limited service duty or to the United States by other hospitals.

The third check was made through the Machine Records Unit, where we obtained information as to the present assignment and organization of each patient.

From these sources the necessary information was obtained on the results of 121 knee arthrotomies out of a total of 124. The remaining three patients were members of the Australian Military Forces, on whom we were unable to obtain complete follow-up information.

SELECTION OF CASES

Early in our overseas experience, we realized the tremendous importance of making a total evaluation of the patient prior to operation. Careful sizing up of the patient as a soldier—his attitude, initiative, and cooperation—had a direct bearing on his postoperative course. An operation may be considered useless from the point of view of the Army when, postoperatively, the patient is discovered to be unfit for duty because of an underlying maladjustment, neuropsychiatric disorder, or for some other mental or physical condition. The other important consideration bearing on the selection of a case for operation was the evaluation of the knee condition, *per se*. Some types of knee derangement carried a favorable prognosis for return to duty, while others did not.

In the latter part of 1942, we adopted a definite policy, the main points of which were:

First, careful selection and evaluation of the patient as a whole;

Second, preoperative and postoperative classification of the patients into two types of cases, those with the "uncomplicated" injuries to the meniscus, and the "complicated" knee cases—those with articular or ligamentous damage, with or without injury to the meniscus;

Third, the institution of a reconditioning course; each patient was required to enter this course after a reasonable time,—usually four or five weeks after operation. Here the patient's course was carefully followed by a medical officer. When the patient had completed his training, he was again evaluated, and then was sent out to the type of duty he was considered capable of performing.

Classifying the patients into "complicated" and "uncomplicated" cases expedited treatment and disposition. The uncomplicated cases were the patients from whom an injured meniscus had been removed, and who demonstrated at the time of the operation an otherwise normal knee joint.

The complicated cases were those in which there were associated changes in the knee joint, in addition to an injured meniscus. These included osteochondritis dissecans, insta-

TABLE I

UNCOMPLICATED MENISCUS CASES

Total number of cases 67. Follow-up complete on 65.

1. Number of patients sent to full military duty 59
   Number of patients remaining at full military duty 50 or 85 per cent.
   - Of the nine who did not remain at full duty:
     - 5 were rehospitalized because of knee complaint.
       - 3 were returned to the United States
       - 2 were returned to limited duty.
     - 1 was returned to the United States because of other medical conditions.
     - 3 were returned to the United States from their units; these were not rehospitalized, possibly were on rotation or leave.
   - Average period of time spent at full duty 10.3 months
     - Number of cases remaining at full duty one year and over 24
     - Number of cases remaining at full duty less than one year 26
2. Number of patients sent to limited service duty from our Hospital 5
   - All remained at limited duty an average of 15 months.
3. Number of patients returned to the United States from our Hospital because of knee complaint 1

Total number of cases 65

4. Total number of patients returned to the United States from our Hospital and other hospitals because of knee disability 4

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bility of the knee joint as a result of injury to the cruciate or collateral ligaments, hypermobility of the patella, appreciable traumatic arthritis, and severe traumatic synovitis.

After operation the favorable uncomplicated cases were returned to full military duty of which there were eighteen different types, 49 per cent. of which was infantry field duty The majority of patients in the group of "complicated cases" were sent to limited duty, or were returned to the United States.

STATISTICAL STUDY

Of the patients admitted to the Hospital because of a knee complaint, 29 per cent required operation.

The average number of postoperative days spent in the Hospital, including the time in the reconditioning course, was sixty-three.

Of the 121 cases on which the follow-up study was complete, sixty-five or 54 per cent were regarded as uncomplicated meniscus injuries (Table I). Twenty-three cases or 19 per cent. were classified as complicated meniscus cases (Table II). The remaining thirty-three cases or 27 per cent. were operated upon for reasons other than a torn meniscus.

TABLE II

COMPLICATED MENISCUS CASES

Total number of patients 23. Follow-up complete on 23.

1. Number of patients sent to full military duty 6
   Number remaining at full military duty 2
   - 4 patients were rehospitalized and were returned to the United States because of knee disability.
2. Number of patients sent to limited service duty 10
   Number remaining at limited service duty 7
   - Of the 3 patients who did not remain at limited service duty:
     - 2 were returned to the United States because of knee disability.
     - 1 was returned to the United States from his unit, but was not rehospitalized (possibly on rotation or leave).
3. Number of patients returned to the United States from our Hospital 7
   - 4 because of knee disability
   - 3 because of other medical conditions

Total number of cases 23

4. Total number of patients returned to United States from our Hospital and other hospitals because of knee disability 10
5. Average period of time at full military duty 12 months.
   Average period of time at limited service duty 13 months.

TABLE III

CASES OF INTERNAL DERANGEMENT WITHOUT MENISCUS INJURY

Total number of cases 34. Follow-up complete on 33.

1. Number of patients sent to full military duty — 9
   Number remaining at full duty 7
   The 2 men rehospitalized were returned to the United States because of knee disability.
2. Number of patients returned to limited service duty — 14
   Number remaining at limited service duty 11
   2 were returned to the United States because of knee disability
   1 was returned to the United States from his unit, but was not rehospitalized.
3. Number of patients returned to the United States from our Hospital — 10

   Total number of cases — 33
4. Total number of patients returned to United States from our Hospital and other hospitals because of knee disability 14
5. Average period of time spent at full military duty 11 months.
   Average period of time at limited service duty 15 months.

These figures show that the patient with an uncomplicated injury to the meniscus can be expected to perform full military duty, if a careful operation is done, and if the post-operative care is rationally carried out.

The men classified as complicated knee cases, on the other hand, will not be serviceable in duties which require excessive use of the knee. Selected patients may make useful soldiers at limited duty, and a few may return to full duty, but they must be equipped to do a specialized type of work. Approximately 43 per cent. of the complicated knee cases were found unfit for any type of duty in a theater of operations, and were returned to the United States. Particularly poor results in this group were found in the cases of moderately severe to severe osteochondritis, and in the knee unstable because of damage to the cruciate ligament. The knees with moderately severe traumatic changes, and without loose-body formation in the joint, responded better after the injured meniscus had been removed.

In the Army Medical Bulletin, May 1944[1], elective surgery of the knee joint was discussed, and the causes for poor results were outlined. Our experience concurs with the opinions expressed therein.

The following are some of the significant facts as to the history, physical findings, and roentgenographic studies in our series of cases.

History

Of the cases in which a torn or injured meniscus was found at operation:

The mechanism of injury was a twist of the knee joint in 98 per cent. of the cases.

A history of locking was elicited in 70 per cent. of the cases, swelling of the joint in 95 per cent., and pain at the time of injury in 97 per cent. We found that it was most important to have the patient describe exactly what took place when his knee "locked".

The number of attacks was significant, and helped to determine whether or not operation should be performed. It can be said, however, that once a meniscus is split longitudinally, it never heals, and recurrent attacks should be expected.

Physical Examination

The most consistent physical findings in the cases in which a torn meniscus was found at operation were:

Atrophy of the quadriceps muscles in 68 per cent. of the cases;

Localized tenderness and abnormal prominence of the meniscus at the joint line in 88 per cent.;

Excess joint fluid in 50 per cent.;

Limitation of motion, particularly in extension, in 63 per cent.

Roentgenographic Examination

Anteroposterior and lateral roentgenograms were taken of all patients. Except for the demonstration of calcified loose bodies and traumatic changes of the articular surfaces,

the evidence of derangement was of a negative nature. We have not in any case used pneumarthrograms as a diagnostic procedure. We do not believe they are necessary, and fear that they may at times be misleading.

Findings at Operation

Of the eighty-eight cases in which the meniscus was injured, seventy-seven or 87 per cent. were of the medial meniscus. Of these seventy-seven cases, the "bucket-handle" type of tear was found in 70 per cent.; in 25 per cent. there were multiple tears; and in 5 per cent., transverse splits. There were eleven cases or 12 per cent. in which the lateral meniscus was injured; seven of these were associated with cystic degeneration of the lateral meniscus. The posterior third of the meniscus was injured in twelve of the above cases: eleven of the medial meniscus, and one of the lateral meniscus. Herniation of the joint capsule in the popliteal region was associated with injury of the medial meniscus in two patients.

Other findings in the series of 121 cases were:

a. Osteochondritis dissecans of the femoral condyles in fifteen patients; in twelve of these, cartilaginous or ossified bodies were present. The lesion was on the medial femoral condyle in eleven cases, usually on the lateral aspect, and on the lateral femoral condyle in four patients.

b. Chondromalacia of the patella was present in eleven patients. In nine of these there was no associated injury to the meniscus.

c. Giant-cell tumor of the knee-joint capsule was found in two patients.

d. Calcification of the split posterior third of the medial meniscus was present in one patient, and ossification in another.

e. Intra-articular ganglia of the patella and quadriceps tendons were present in one patient.

f. An anatomical variation, consisting of a congenital veil or membranous septum, dividing the knee completely in the anteroposterior plane, was present in one patient.

Six of the 121 patients had been previously operated upon in other hospitals. On all of these further exploration was done, and in all we found tears or partial detachment of an incompletely removed posterior portion of the medial meniscus. After operation all of these patients were returned to duty.

In five of the 121 arthrotomies, the findings were within normal limits. Two of these presented so-called "hypermobile menisci"; they were removed, but we did not feel certain that they were the causes of internal derangement. All were sent to duty, four to full military duty, and one to limited service duty, where they remained. It is significant that in only one of this group was there a history of "locking" of the knee.

Postoperative Complications in 121 Cases

a. Postoperative sepsis—one case. This occurred during a period when many septic battle casualties were being received. After drainage and Kirschner-wire traction, the patient had gained flexion of 50 degrees, and complete extension at the time of evacuation.

b. Temporary sciatic nerve palsy—four cases. This occurred because the tourniquet was placed too close to the ischial tuberosity, where the sciatic nerve is relatively unprotected. All recovered completely in a few weeks.

c. Thrombophlebitis—one case. This subsided, and did not interfere with patient's return to full duty.

OPERATIVE TECHNIQUE

Prior to operation, careful instruction in quadriceps-setting exercises is given to the patient. Forty-eight hours prior to operation a graphic temperature chart is begun, and throat culture is taken for hemolytic streptococcus. With a temperature of over 99 degrees, or when more than an occasional streptococcus is present in the throat culture, the operation is cancelled. The skin is prepared forty-eight hours and again twenty-four hours before the operation.

A thigh tourniquet, placed about four inches below the level of the ischial tuberosity, is used in all cases. This consists of a soft rubber tube, one-half inch in diameter, applied twice around the thigh over a Turkish towel.

Incision: When we are reasonably certain that the patient has an uncomplicated meniscus injury we use the "combined" incision[2], which begins three-eighths of an inch posterior to the femoral epicondyle, and curves downward and forward to the joint line and to the mid-portion of the patellar tendon. On the inner aspect of the knee, the patellar branches of the internal saphenous nerve are identified, and retracted. The anterior compartment is opened with a curved incision, in front of the collateral ligament; this allows adequate inspection of the anterior joint space. A second capsular incision, perpendicular to the joint line, is made posterior to the tibial or fibular collateral ligament, as the case may be, and the posterior joint space is exposed. The anterior portion of the meniscus is dissected free through the anterior incision, and passed backward between the collateral ligament and the joint space and removed through the posterior incision. With cases in which a more adequate exposure of the joint is desired, or when the diagnosis is not reasonably definite, the knee is opened by a parapatellar incision three or four inches in length (7.5 to 10 centimeters), and, if necessary, it is enlarged superiorly or inferiorly. Careful inspection of the knee joint is carried out routinely, including the opposite meniscus, the articular surfaces of the femur, tibia, and patella, the cruciate ligaments, the synovial membrane, and the infrapatellar fat pad. No. 60 cotton is used for ligatures, and No. 40 cotton for sutures.

Following closure of the joint, a soft compression dressing is applied, and the leg is bandaged with a stockinette roll or an elastic bandage from toes to groin. The tourniquet is then removed. This type of complete bandage may help to prevent postoperative phlebitis. The leg is supported by a pillow. Traction is never used. On the first postoperative day, quadriceps-setting exercises are begun. The patient is not allowed up until he can actively raise his leg with the knee straight. He is then required to use crutches until he has demonstrated a correct gait. For physiotherapy he is given graduated exercises, followed by bicycle-riding, rope-jumping, and exercises on a rowing machine. From the physiotherapy clinic the patient is sent to the reconditioning area.

CONCLUSIONS

1. In order to prognosticate which patients with internal derangement of the knee will return to full duty after operation, careful preoperative evaluation of the patient as a whole is essential. This involves the sizing up of the individual from the psychological standpoint; the taking of a detailed history as to the mechanism of injury; a systematic and thorough physical examination including: inspection, palpation, motions, stability, stance, and examination of the joints above and below the knee. The opposite or normal knee should always be examined for comparison.

2. Usually the patients can be classified into two groups: (1) those having uncomplicated injuries to the meniscus, and (2) those with damage to the articular surfaces or ligaments, which may or may not be associated with injury to the meniscus.

3. The vast majority of patients with an uncomplicated meniscus injury can be returned to, and will remain at, full military duty, if a careful operation is carried out, and if the patient is reconditioned prior to his discharge from the hospital.

4. Patients whose knee disability is due to, or complicated by, articular damage or instability of the joint should not be operated upon in an overseas theater, unless symptoms are sufficient to cause severe pain or locking of the joint.

5. Exceptions to the previous statement may be made in so-called "key personnel" who, after operation, can return to limited service, not requiring excessive use of the knee.

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ANTERIOR TRANSPOSITION OF THE PERONEAL NERVE FOR TRACTION PARALYSIS

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Peroneal palsy is, fortunately, among the more unusual of the complications associated with fractures about the knee. Its occurrence appears to have been attributed principally to direct contusions or to pressure against the nerve. The degree of this pressure need not be excessive, and, in the opinion of Selig, may result from the improper application of adhesive plaster to the leg, even in the absence of fracture.

Platt [5] first called attention to the fact that this nerve may exhibit paralytic phenomena as a result of clinical conditions associated with excessive traction. These may include instances arising as a consequence of accident or trauma incidental to the operative correction of genu valgum. In his first communication in 1928, Platt especially emphasized his belief that the nerve lesion is a concomitant of fractures of the styloid process, as contrasted with fractures of the neck of the fibula, although it is expressly stated that "the external popliteal nerve lesion which accompanies separation of the fibular styloid, is a true-primary injury which bears no *casual* relation to the treatment of the fracture".

In 1931, Watson-Jones, apparently unaware of Platt's earlier observation, reported a case which he believed to be unique. This concerned a man of fifty-six who had been knocked down by a motor car, and suffered an avulsion of the styloid process of the fibula, with incomplete paralysis of the external popliteal nerve (common peroneal). During operation to reduce the fracture, the peroneal nerve was "found not to have been ruptured, although recent hemorrhage into the sheath was evident. The styloid fragment was replaced and sutured with braided silk, and ten weeks later, when the plaster was removed, the paralysis had completely disappeared."

Watson-Jones noted that: "Three features of interest are presented in this case. Although crack fractures of the upper end of the fibula are not uncommon, complete avulsion with wide separation is rare. . . . Secondly, complete recovery of peroneal palsy is unusual; but as a rule the nerve is injured by contusion, whereas in this case the block has been purely 'physiological' and it is attributable to momentary stretching of the nerve trunk. Finally, the close resemblance between the clinical syndromes in knee and elbow is remarkable. In each condition, in consequence of a lateral strain there is subluxation of the joint, avulsion of capsule, and aponeurosis with an attached fragment of bone, displacement of the fragment into the joint, and coincident traction injury of the nerve."

In 1940 Platt [6] elaborated the clinical picture, and described the palsy as an intrinsic part of the "ligamentous-peroneal syndrome characteristic of adduction injuries of the knee joint". As its hyphenated designation indicates, the syndrome is a combination form, defined (a) by the presence of peroneal paralysis, and (b) by a triad of signs characteristic of adduction injuries to the knee joint,—rupture of the lateral capsule, avulsion of the styloid process of the fibula, and avulsion of the biceps tendon from the fibular attachment.

Although the validity of each of these syndromes may be accepted, it is very questionable whether or not the combination may properly be considered as a true syndrome. Experience would seem to indicate that severe damage to the ligamentous apparatus of the knee occurs more frequently alone than in combination with injuries to the peroneal nerve. Even an avulsion fracture of the fibular styloid may occur without peroneal palsy[4]. On the other hand, paralysis in the distribution of this nerve may and does occur without injury to the ligamentous apparatus or fracture of the styloid process of the fibula. While

either one of these two syndromes may arise as a result of the forces of excessive traction, the association of the two does not appear to be consequential, as will be seen in the following cases.

CASE REPORTS

CASE 1. Anna P., forty-one years old, was seen on January 26, 1943, about seven weeks after an automobile injury. On December 8, 1942, the patient had been thrown against the dashboard of her automobile, and had suffered a severely comminuted fracture of the upper end of the right tibia The leg was promptly immobilized in a Thomas splint, and roentgenograms, taken upon her admission to another hospital, showed excellent alignment of the fractured fragments. Unfortunately, the splint was removed, and a plaster-of-Paris cast was applied, with the knee in complete extension. Ten days later the patient was discharged from the hospital, but on January 18, 1943, she returned to the hospital because the plaster had become loose. New roentgenograms showed unsatisfactory position. The lower fragment was hyperextended, and there was definite backward angulation at the level of the fracture. The distal tibial fragment and the fibula had been displaced proximally, and the tibial plateau was increased in diameter. A new plaster was applied, but shortly thereafter the patient began to complain of a tingling in the toes

Examination disclosed a moderate increase in the diameter of the right knee This was clearly caused by the projection of the fibular head beyond the lateral surface of the tibial condyle. Flexion of the knee was possible to 90 degrees, extension to 170 degrees. No lateral instability of the knee joint could be elicited. Due to posterior angulation of about 15 degrees, the leg presented the appearance of a true genu recurvatum. No false point of motion could be clinically demonstrated, and there was no evidence of peroneal palsy.

Roentgenogram (Fig 1-A) taken on January 26, 1943, showed a comminuted intra-articular fracture of the proximal end of the tibia. The distal fragment showed posterior displacement of one centimeter. Early callus formation was present. Though its significance was not specifically appreciated until later, attention should be called to the fact that there was a displacement of the fibular head, with an increase in the transverse diameter of the upper end of the tibia By comparison with the bicondylar diameter of the upper end of the femur, it could be observed that the distance of the fibula from the tibial shaft was definitely greater than normal. Fracture of the fibula or its styloid process was not seen

In the hope that some of the deformity could be overcome, skin traction, using four pounds of weight, was applied. The following day the patient began again to complain of pain in the leg Two days later, complete dropping of the foot and a loss in the power of the peroneal muscles were noted. There was hypaesthesia to pin prick in the peroneal-nerve distribution; and pressure over the nerve, as it wound around the fibula, elicited tenderness Roentgenograms showed no essential change in position. Since the palsy appeared so promptly following the application of skin traction, it seemed to be the direct cause of the nerve symptoms. Because of the excessive extension of the distal fragment, it was believed that the skin traction had resulted in a hyperextension type of peroneal palsy. Although all traction was promptly discontinued, there was no abatement of symptoms

Neurological consultation confirmed the presence of the nerve lesion Surgical exploration was cautioned against, and conservative therapy was advised Heat, massage, and electrotherapy were carried out over a period of two weeks, but without any sign of improvement. It was felt that the lack of any response to therapy indicated the continuing action of a force other than the skin traction Study of the roentgenograms gradually gave rise to the conclusion that this force came from the tension caused by an increase in the tibiofibular distance It was determined to explore the nerve with this in mind.

Under general anaesthesia on February 18, 1943, an incision, four inches (ten centimeters) long, was made over the lateral aspect of the leg, exposing the peroneal nerve The nerve was found to be completely intact, but over the head of the fibula it was reddened, markedly flattened, and quite obviously under considerable tension This was clearly due to the resistance offered by the fibular attachment of the deep fascia, which actually snapped as it was cut across to release the nerve The nerve was then translocated forward Although the nerve tension was considerably reduced, it was not completely relieved. In its normal position the fibular head presented a bony resistance to the nerve, and it was felt that the tension on the nerve could be overcome only by resecting the head so as to reduce the distance to be traversed by the nerve. The collateral ligament and the biceps tendon were thereupon dissected away, and the fibular head was excised (Fig 1-B) The nerve could then be dropped loosely into the hiatus thus created The biceps tendon and the collateral ligament were sutured to the tibia, and the wound was closed The postoperative convalescence was uneventful, and the wound healed by primary intention.

Two days after the operation, the patient noted a return of sensation along the inner and outer borders of the foot Slight power in the anterior tibial and the peroneal muscle began to reappear. On the fifth day, sensation was fairly normal, and there was obvious restoration of power in the foot, although the extensors were still quite weak. On March 6, the patient was permitted to begin weight-bearing with the aid of crutches, and her discharge from the hospital was recommended. Upon her

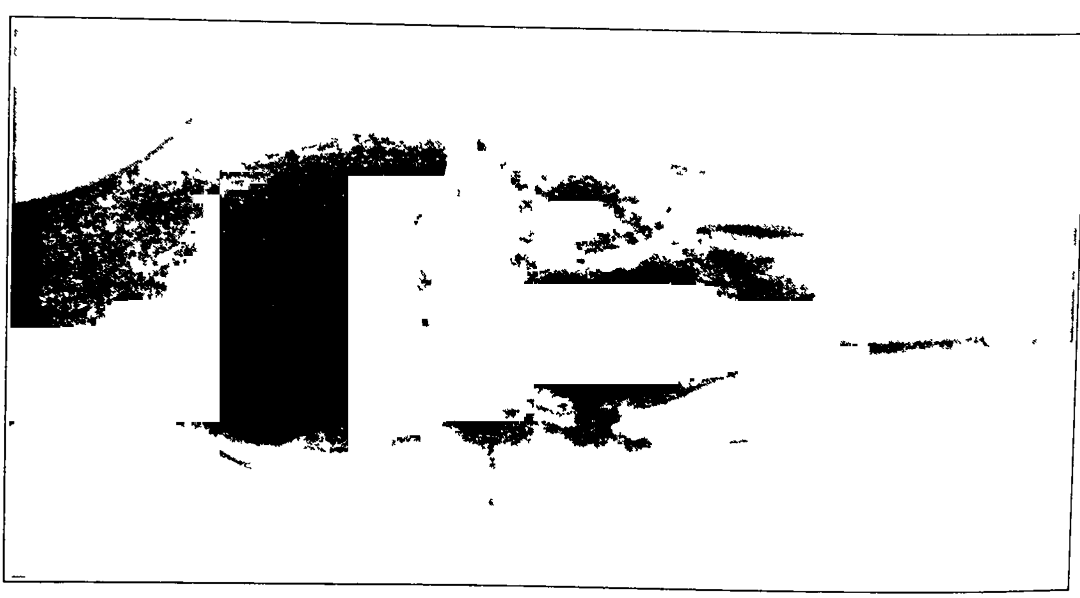

Fig 1-A
Case 1. Comminuted fracture with increased tibiofibular distance due to the increase in the width of the tibial condyles.

Fig. 1-B
Same as Fig 1-A, after resection of the fibular head to accommodate the peroneal nerve

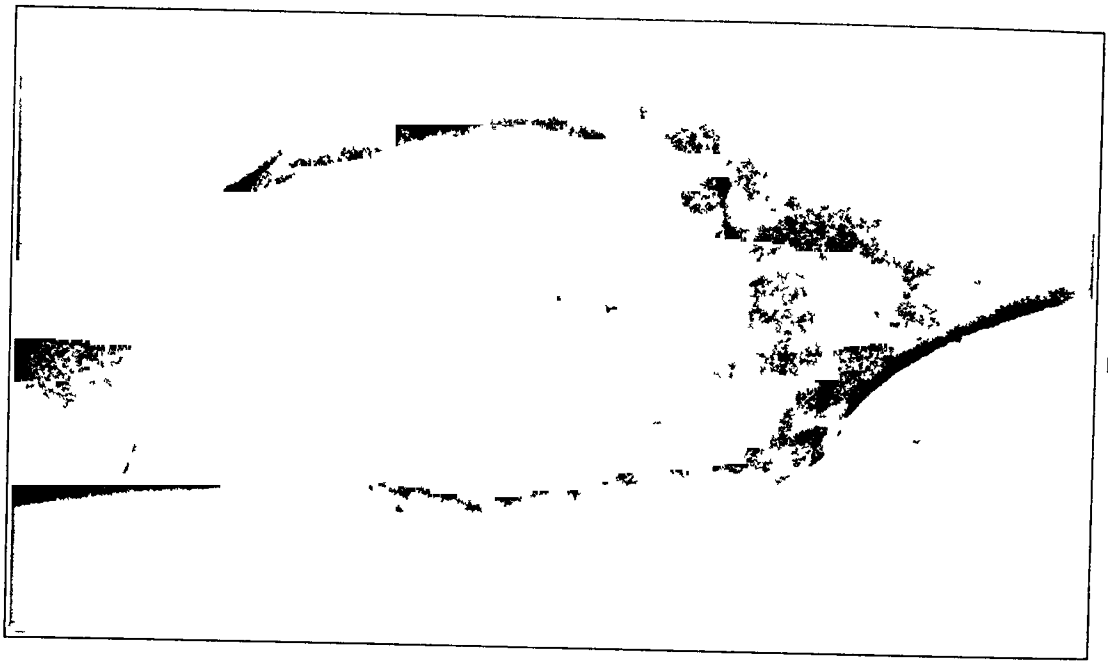

Fig 2
Case 2 Avulsion fracture of the fibular head The comminuted styloid process has been pulled up to the level of the knee joint.

return home she was given electrotherapy and gentle massage. There was slow but progressive return of function. By the middle of July the patient was walking normally, without any aid or support. The power in the foot muscles was normal, but some limitation in complete flexion of the knee persisted, and on extension the recurvatum deformity was still noted. Apart from this, the patient disclaimed any disability, and she has since resumed her normal activities.

The preoperative clinical picture and the appearance of the nerve at operation are readily explained on the basis of excessive traction. It must be presumed that the mushrooming of the upper end of the tibia, and the subsequent outward and upward displacement of the fibular head resulted in an increase in the distance from the fibular neck to the point of distribution of the peroneal nerve, in the muscles of the anterior and lateral compartments of the leg. Because of the fixation of the nerve as it curves around the fibular neck, any increase in the tibiofibular distance necessarily imposes a traction force on the portion of the nerve distal to the point of fibular fixation. That so slight an increase in tension as might be occasioned by mild flexion of the thigh (with knees extended) could give symptoms of tingling, indicated the slight margin of tension beyond which injury to the nerve supervened. It may readily be conceived that the effect of continuous traction was such as to lead to motor as well as to sensory disturbances.

The failure to respond to conservative treatment, and the relatively rapid response following removal of the bony obstruction, represented by the fibular head, clearly lend support to Platt's conception, and justify his recommendation that all cases of peroneal traction palsy merit early exploration. The fact that this condition arose seven weeks after injury, in the absence of fracture of the fibula, and as a result of a mechanism which usually does not produce lesions of the ligaments of the knee, serves to indicate the separate nature of the ligamentous and the peroneal syndromes. This is further emphasized by the fact that fractures of the fibular head need not necessarily be associated with peroneal palsy, as the following case illustrates.

Case 2. Abraham S., seventy-five years old, was struck across both knees by a falling bale of hay. The patient was immediately incapacitated, and roentgenograms revealed fractures of both legs. There was a comminuted depressed fracture of the articular surface of the head of the left tibia. On the right side there was a comminuted fracture of the head of the fibula. A triangular fragment of bone, measuring seven-eighths by one-half of an inch (2.2 by 1.2 centimeters), and a smaller linear fragment had been broken off; they had become displaced and rotated cephalad. The head of the fibula was dislocated slightly externally and anteriorly from its normal position (Fig. 2).

The fracture of the left leg appeared to be of the type seen in "bumper" fractures; that of the right leg resembled the fracture described by Watson-Jones, and seemed to belong more in the category of the hyperadduction injuries described by Platt.

Although there was no evidence of peroneal palsy, the case seemed to fall so completely into the category described by Platt that exploration of the area seemed justified. Under local anaesthesia, a three-inch (7.5 centimeters) longitudinal incision was made, and the fascia was incised. A somewhat tense peroneal nerve was found, lying in the depression between the fractured portions of the fibula. The upper end of the peroneus longus and the fascia remaining attached to the fibular head were severed, so that the nerve could be easily translocated forward. This resulted in a relative increase in the length of the nerve, and, therefore, a complete disappearance of the tension. Because of the patient's age and general condition, the bony fragment was anchored in position without extensive efforts being made for anatomical reposition. The muscle was thereupon sutured back into position, and the fascia was reunited over the nerve. A straight-leg plaster was applied for a period of three weeks, and thereafter active motion was gradually begun. Despite the fact that the avulsed fragment was never replaced, the patient at no time gave evidence of either motor or sensory disturbance in the distribution of the peroneal nerve.

It is, of course, impossible to assert that the slight degree of tension noted in this case would have been sufficient to cause an ultimate traction palsy. It is consequently impossible to maintain that the treatment undertaken was justified by the outcome. The absence of true paralysis may be due to the fact that the nerve lay in the depression between the two fractured fragments of the fibula. In this way, a compensating increase in length of the nerve had been achieved, and the possible paralyzing effect of excessive traction had been avoided.

Fig. 3

Anatomical specimen. The fascia has been reflected to show the two heads of the peroneus longus. The peroneal nerve is seen crossing the lateral aspect of the fibula, and curving medially in the groove between the tibial and fibular origins of the peroneus longus.

DISCUSSION

The importance of traction in the etiology of nerve lesions has been studied by Highet and Holmes[1], who made a report on a series of eight cases in which in general they agreed with the observations of Platt. However, in four of their cases, in which extensive resection and nerve suture were performed, failure resulted. In commenting upon this they state: "This failure is understandable in those cases in which the nerve was completely divided, as it was due to the inability of the regenerating fibres satisfactorily to bridge the gap between the stumps. But in those cases in which the nerve-trunk retained a considerable degree of continuity, the absence of recovery cannot be accounted for so simply. It cannot have been due to damage to the central neurons or to failure of the axons to regenerate through the lesion, for in all cases in which there was some continuity of the nerve, very many non-myelinated axons were found to have grown out to its distal end. The most significant observation is that these axons had failed to increase to a normal diameter, and most of them had failed to become myelinated." It was the belief of these writers that this failure was due to tension itself. In a later paper [2] Highet and Saunders showed experimentally that extensive changes, including degeneration of the central portion, rupture of the neurolemma, oedema, and extensive fibrosis in and about the nerve were the results of stretching.

From the fact that release of the peroneal nerve in Case 1 resulted in prompt subsidence of paralytic phenomena, it seemed reasonable to review the anatomy of the peroneal nerve in the region of the fibular head. Usually the peroneal nerve is described casually as coursing down behind the head of the fibula, until it reaches the neck around which it winds. This does not appear to be entirely accurate. Examination of the anatomical specimen (Fig. 3) will reveal that the nerve runs along the posterior border of the biceps. It then courses obliquely downward, forward, and medialward along the lateral aspect of the upper end of the fibula between the two heads of the peroneus longus, until it reaches the level of the fibular neck. The relationship of the nerve to the origin of the peroneus longus is of the utmost importance, and is described by Wood Jones in the following manner: "The tibial origin is from a small area on the upper extremity of the bone immedi-

ately in front of the articular facet of the superior tibio-fibular joint, and with some of the fibres of the anterior ligament of this joint additional bonds of origin are made. On the fibula it arises from the anterior and lateral aspect of the head and from the upper two-thirds or so of the lateral surface of the shaft." These two origins "are separated by an interval (which may be likened to the musculo-spiral groove on the humerus) in which the lateral popliteal (peroneal) nerve lies and give origin to its musculo-cutaneous (superficial peroneal) branch".

As the peroneal nerve winds around the neck of the fibula, it makes an almost right-angled turn around the tibial head of the peroneus longus. But even more important than this is its relationship to the fascia lata which lies superficial to the peroneus longus muscle, and takes a firm attachment to the fibular head at a point just above and slightly more lateral to the origin of the long head of the peroneus longus. Both the muscle and the fascial attachment act as a fulcrum around which the nerve changes its course. Since the nerve is covered by the deep fascia, this knee-like change in direction acts as a fixed point against which traction may be exerted.

In view of the analogy which Watson-Jones noted between the valgus strain of the ulnar nerve at the elbow, and the varus strain of the peroneal nerve at the knee, it was only natural to attempt, at the knee, the sort of nerve transplantation which Platt performed at the elbow. This can be easily accomplished by making an incision over the upper end of the fibula. The biceps is identified, and the peroneal nerve is isolated at a level above the styloid process of the fibula. By following the nerve downward, the intermuscular space is easily defined, and the fascia and the medial head of the peroneus longus muscle are detached. When this has been done, the peroneal nerve can be transposed medially so that it winds around the lateral to the anterior aspect of the biceps tendon. By descending directly to its distribution in the muscles of the anterior compartment of the leg medial to the superior tibiofibular joint, the right-angled bend of the nerve is eliminated (Fig. 4). A relative increase in the length of the peroneal nerve, sufficient to provide for excessive traction due to increase in the tibiofibular distance, can be

FIG. 4

Anatomical specimen. The fascia and the tibial origin of the peroneus longus have been detached from the fibular head. As compared with Fig 3, the peroneal nerve can be seen displaced forward out of its groove Crossing the biceps, it lies medial to the fibular head, and ascends directly to the muscle, instead of following a right-angled course around the lateral origin of the peroneus longus.

accomplished. Where it is felt that simple transposition will be insufficient, excessive traction on the nerve can be obviated by resection of the fibular head as in Case 1.

SUMMARY

Excessive traction on the peroneal nerve, with resulting paralysis, may be removed by the operation of anterior transposition of the nerve, after the tibial head of the peroneus longus muscle has been detached. In those cases in which simple transposition is insufficient, resection of the fibular head offers a means of overcoming relative disproportion between the nerve and the tibiofibular distance.

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ACUTE ISCHAEMIA OF THE ANTERIOR TIBIAL MUSCLE AND THE LONG EXTENSOR MUSCLES OF THE TOES

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Recently a peculiar type of vascular disturbance, localized to the anterior fascial compartment of the leg, has been observed in young and otherwise healthy soldiers. No acute trauma has been associated with the onset of such disturbance. The following conditions have been considered and eliminated in the differential diagnosis: emboli, aneurysm, Raynaud's disease, thrombo-angiitis obliterans, arteriosclerosis, periarteritis nodosa, peritendinitis crepitans, phlebitis, cellulitis, fibrositis, rheumatoid arthritis, anterior poliomyelitis, myositis due to bacteria or parasites, and tumors of the muscle. The characteristic clinical symptoms and findings are as follows:

1. Sudden onset of severe pain in the anterior portion of the leg;
2. Rapid development of swelling that is most marked over the anterior fascial compartment;
3. Mild to intense erythema and glossiness over the anterior fascial compartment;
4. Slight to complete interruption of function of the common peroneal nerve.

The clinical course is illustrated by the following case reports.

CASE 1. A white soldier, aged twenty-three, was admitted to the Section of Septic Surgery, complaining of pain in the anterior aspect of the right leg, which had begun during a twenty-mile march on the previous day. There was an intense erythema over the anterior fascial compartment of the right leg. There was marked swelling of the leg, and a complete peroneal palsy. Temperature was 98.6, pulse was 74 and regular. The blood count, including differential, serology, and urinalysis were normal.

Incision of the anterior fascia cruris was done six days later. The anterior tibial muscle bulged out of its fascial compartment, as though it were under considerable pressure. The muscle was gray and avascular when first exposed, but it appeared to regain some circulation while under observation. A photomicrograph of a section of this muscle is shown in Figure 2. The incision could not be closed due to marked retraction of the skin edges. Healthy granulations developed over the muscle, allowing application of pinch grafts. Complete epithelization of the wound took place. However, there was no return of function to the ankle and toe extensors or to the peroneal muscles, and a permanent foot-drop resulted.

CASE 2. A white soldier, aged twenty-six, of Anglo-Saxon descent, was admitted to the Section of Septic Surgery, complaining of pain and swelling of the right leg. The family history was irrelevant. He smoked from twenty to thirty cigarettes daily, and drank about one quart of whiskey per week. The only injury had been a sprain of the right ankle in childhood. For several months he had noted pains in both legs during forced marching. He had experienced a sudden sharp throbbing pain in the anterior part of the right leg, while walking the previous evening.

Physical examination was essentially normal, except for the right leg. The temperature was 98.6, pulse 78 per minute and regular; blood pressure 120/70. Laboratory findings were as follows:

Red Blood Cells, 5,300,000
  Hemoglobin 100 per cent.
White Blood Cells, 12,950

Polymorphonuclear neutrophils	74
Lymphocytes	20
Monocytes	6

Reaction to the Kahn test was negative; the sedimentation rate was six millimeters for the first hour; urinalysis showed nothing significant.

The patient was first seen by the orthopaedic consultant two days after admission. Marked swelling and moderate erythema of the anterior surface of the right leg were apparent. There was a complete right peroneal palsy. The pulsation of the right dorsalis pedis was faintly palpable, but the pulsation of the right posterior tibial artery was very full and strong. Treatment was instituted by infiltrating the right first, second, and third lumbar sympathetic ganglia with a solution of 1 per cent. procaine. A definite warming of the leg was produced within a few minutes. The sympathetic block was repeated, and a spinal anaesthetic of 100 milligrams of procaine was given three hours later, with a satisfactory warm-

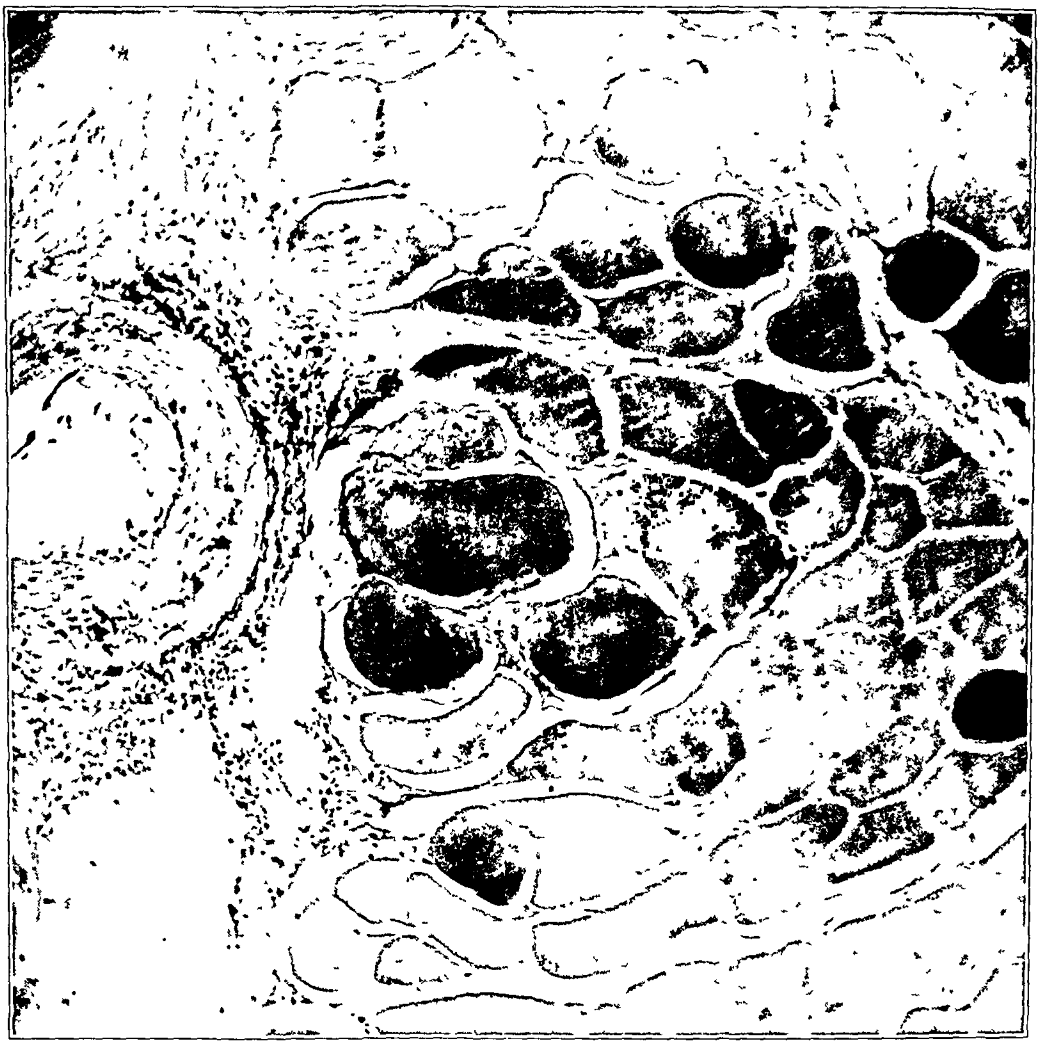

Fig. 1
Photomicrograph (× 120) of anterior tibial muscle three days after onset of symptoms. Section stained with hematoxylin and eosin.

ing of the entire right leg. A definite dorsiflexion of the right second and fifth toes was observed six hours after the second sympathetic block. However, the right anterior tibial muscle could be easily palpated as a stony hard mass. At operation a complete vertical incision was made through the anterior fascia cruris. The muscle immediately bulged anteriorly, exposing a gray, oedematous belly. Patches of muscle about two to three centimeters in diameter and of a port-wine color were observed. About 50 per cent. of the muscle was débrided until retractile and bleeding portions were encountered. The bleeding was not normal, but it was hoped that with the release of the fascia some collateral circulation would be established. A culture of the muscle showed no growth. A photomicrograph of this muscle is shown in Figure 1. The patient remained essentially afebrile, but a foul odor developed about the right leg. He was again operated upon thirteen days following the first operation. The entire anterior tibial and extensor hallucis longus muscles were found to be gangrenous, and were removed by finger dissection. The anterior tibial artery was found to be pulsating normally at the level of the opening in the interosseous membrane, but this pulsation rapidly diminished, so that it could not be felt two centimeters distally. A gray firm mass, 2.5 centimeters in diameter and one centimeter thick, was found encircling the anterior tibial vessels eight centimeters from the inferior edge of the opening of the interosseous membrane. A segment of the anterior tibial artery and vein, fifteen centimeters in length, and including the mass, was excised between ligatures. No oedema or color changes on shifting of position developed in the foot. Complete healing of the wound took place. There was return of excellent function to the peroneal muscles and short extensors of the toes. The patient was able to walk quite well with a light spring drop-foot brace. All studies of the cardiovascular system have been negative, except for the lesions of the anterior tibial vessels.

PATHOLOGY

The microscopic picture of the affected muscles is shown in two stages early in the disease. Figure 1 is a high-power photomicrograph of a section of muscle made three days after the onset of symptoms, revealing a marked enlargement, swelling, and intra-

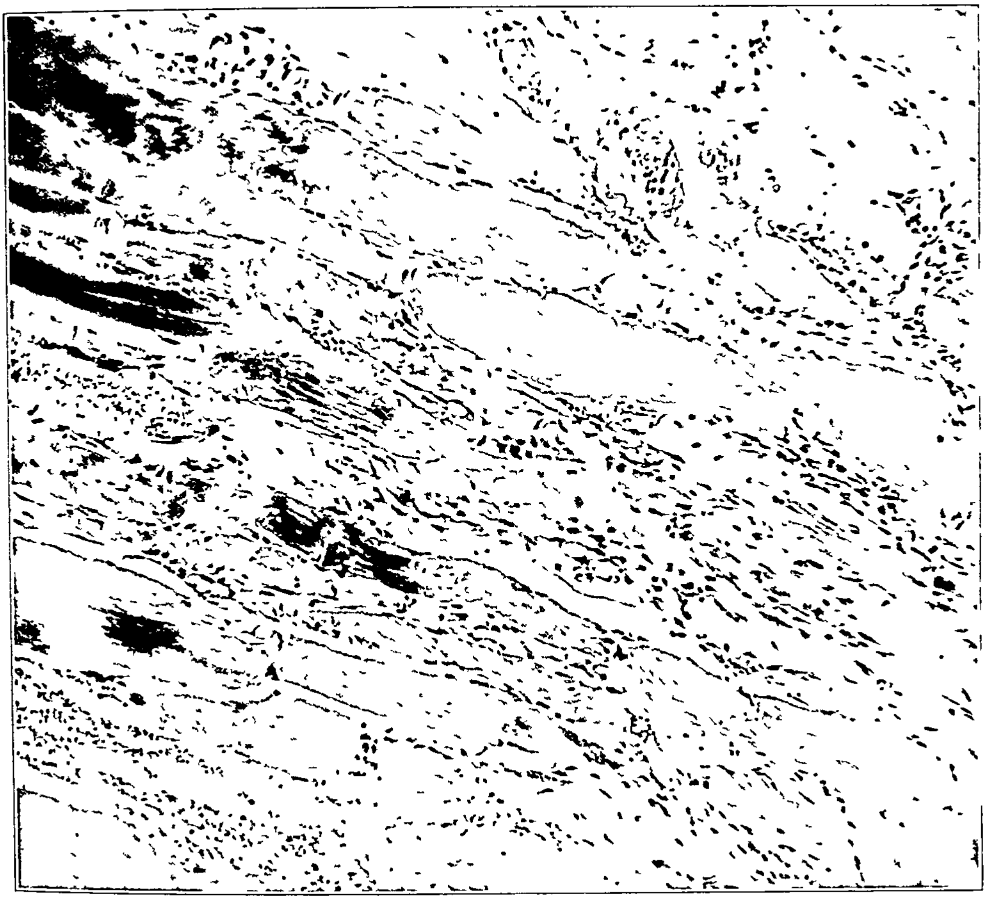

FIG 2
Photomicrograph (× 120) of anterior tibial muscle six days after onset of symptoms Section stained with hematoxylin and eosin

fibrillary oedema of the muscle cells. The muscle cells have lost their striations, and some of them are undergoing necrosis. There is an exudate of serum in some cells between the muscle fibers The blood vessel shows the same type of degenerative process that is found in the muscle cells. There seems to be an increase in fibrosis about the vessel, and there is a fresh exudate of polymorphonuclear leukocytes and round cells in the adventitia of the vessel and in the surrounding fibrous tissue. There is also a moderate cellular exudate in the media of the vessel.

Figure 2 is a high-power photomicrograph of a section of muscle six days after the onset of symptoms, showing fragmented pieces of muscle fibers undergoing various degrees of degeneration. Some of these are enlarged and oedematous. Others are necrotic, and are being absorbed by an infiltrate composed of round cells, macrophages, atypical giant cells, and fibrous tissue. All of the muscle cells have lost their striations Many of the capillaries between the muscle fibers are greatly dilated, probably because of the loss of a supporting wall formed by the muscle fibers.

In short, the section shows degeneration and necrosis of muscle, and replacement of this process by young fibrous tissue, macrophages, round cells, and giant cells. These pathological changes took place within six days after the onset of symptoms. The end result of this pathological process would be complete replacement by dense fibrous tissue of the degenerated and necrotic muscle cells. In other parts, where large areas of the muscle may be involved, the process of absorption of necrotic tissue and replacement by fibrous tissue may not be great enough to cope with the large areas of necrosis, and a necrotic sequestrum of muscle may result, as described by Bristow and by Griffiths.

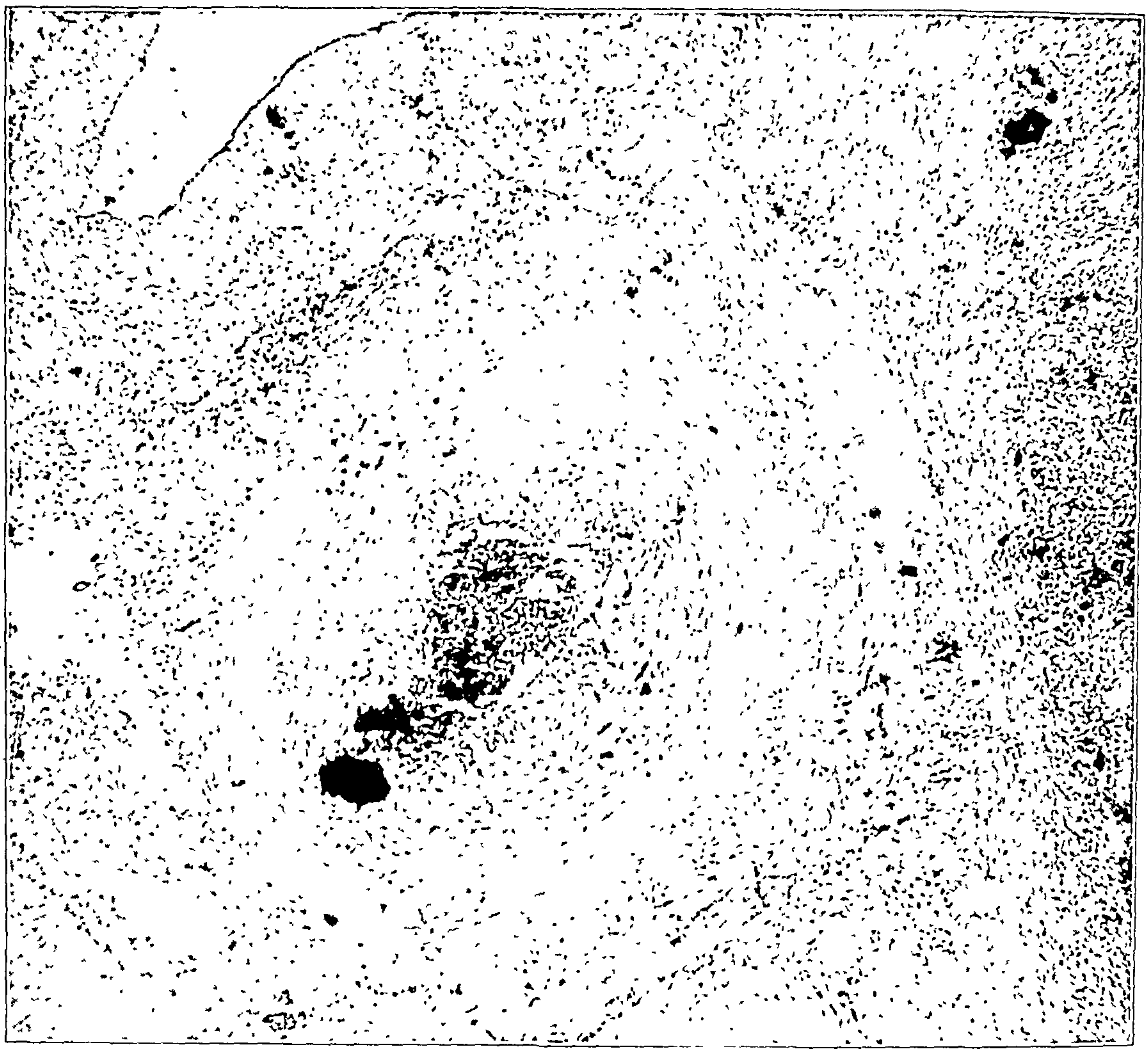

FIG. 3

Photomicrograph (× 44) of anterior tibial artery and portion of the anterior tibial vein sixteen days following onset of acute symptoms. Section stained with hematoxylin and eosin.

The microscopic picture of the vessels involved in the ischaemia of the anterior tibial muscle and long extensors of the toes is shown in Figure 3. This low-power photomicrograph of the anterior tibial artery reveals a marked thickening of all the layers of the artery. The lumen is narrowed. The intima is thickened, and there is reduplication of the internal elastic membrane. The muscularis is hypertrophied, somewhat fibrotic, and contains an occasional round cell. The adventitia is greatly thickened, and also has round-cell infiltration. The periarterial tissues are markedly fibrotic, and densely infiltrated with a cellular exudate, consisting of round cells, plasma cells, and polymorphonuclear leukocytes. The adjoining vein is also involved in this pathological process. The marked fibrosis of the adventitia and of the periarterial tissues is obviously of long standing, and antedates the changes in the muscle shown in Figure 1, which was taken from the same patient.

Pathogenesis

The cause of the fibrosis of the media, adventitia, and periarterial tissue of the anterior tibial artery is subject to conjecture. Chronic trauma has been advanced as the cause of arterial lesions by Learmonth, Blackwood, and Richards. They described four cases of localized arterial thrombosis of undetermined origin. The brachial artery was thrombosed in one patient, and the femoral artery in three patients. They demonstrated the histological sections of the arteries in two cases, which revealed some similarities to the section presented here. They concluded, by exclusion, that trauma was the causative

agent. Lowenberg affirmed that the use of a chipping hammer, and the operation of a stiff foot pedal on a tractor were factors in the production of arterial thrombosis.

Vogt observed soldiers suffering from ischaemia of the anterior tibial muscle, and concluded that continued sliding contact between the anterior tibial vessels and the edge of the aperture in the interosseous membrane produced an irritation leading to vasospasm and resultant ischaemia. This theory is not substantiated by our operative findings in Case 2.

Sirbu, Murphy, and White described ischaemia of the anterior tibial muscle in two soldiers. In one soldier, the ischaemia developed following repair of a hernia of a small muscle, and in the other soldier, ischaemia of the anterior tibial muscle of both legs followed as a result of marching. These writers believe that there is a direct relationship between excessive marching and circulatory disturbances in the anterior tibial muscle.

Howard has studied the chemical and histological changes in the muscle of patients having peritendinitis crepitans. This condition develops when individuals perform certain repeated, rapid motions to which they are unaccustomed, or when they continue to use a muscle that has suffered a direct trauma.

The primary pathological change is exhaustion of the muscle, with retention of lactic acid, and a depletion of muscle glycogen. Histologically the venules are thrombosed; all tissues are oedematous; hemorrhage is present in areolar tissue and muscle; and fibrin is deposited about the peritenon in clumps. The muscle fibers have lost their cross striations, and they may be hyalinized in mild cases, or they may be frankly necrotic in severe cases.

Howard believes that all of these changes arise from fatigue and muscle exhaustion, and not from bacterial infection or so-called toxic conditions. His excellent work may explain the onset of severe ischaemia in soldiers after marching. The continued motion of picking up the foot while marching is accomplished by the anterior tibial muscle and long extensors of the toes These muscles become swollen when they are exhausted, and undergo the chemical and histological changes described above.

If the circulation to these muscles is already impaired by fibrosis of the anterior tibial artery, the circulation becomes definitely inadequate with the development of the increased pressure in the closed fascial space. Peritendinitis crepitans does not occur because of the ischaemia and the consequent absence of hemorrhage and deposition of fibrin.

No specific factor has been proved to be the causative agent of the arterial changes. It may be surmised that the hypertrophy and fibrosis of the media, and the fibrosis of the adventitia and periarterial tissue are the results of repeated overwhelming demands made upon the anterior tibial artery. Involvement of the adventitia may cause a reflex vasoconstriction that affects the entire collateral network. This has been demonstrated experimentally and clinically by Leriche. The additional factor of swelling of the muscle, due to chemical and histological changes

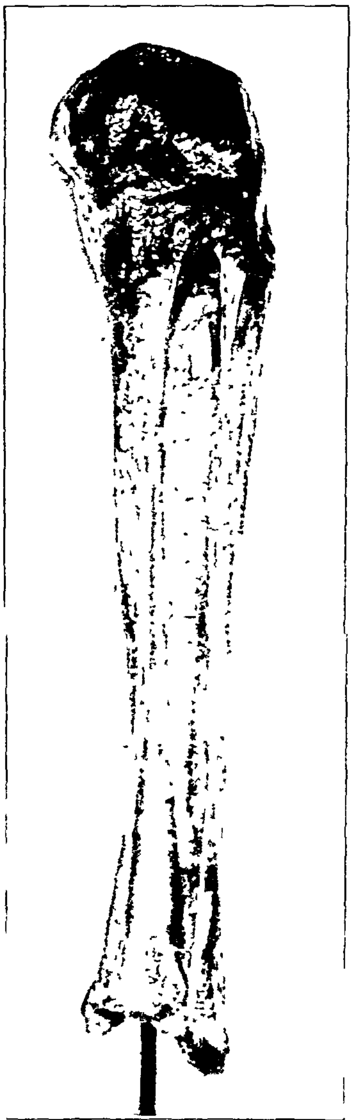

Fig. 4
Dissection of the fascia of the leg (*From the Department of Anatomy, University of California Medical School.*)

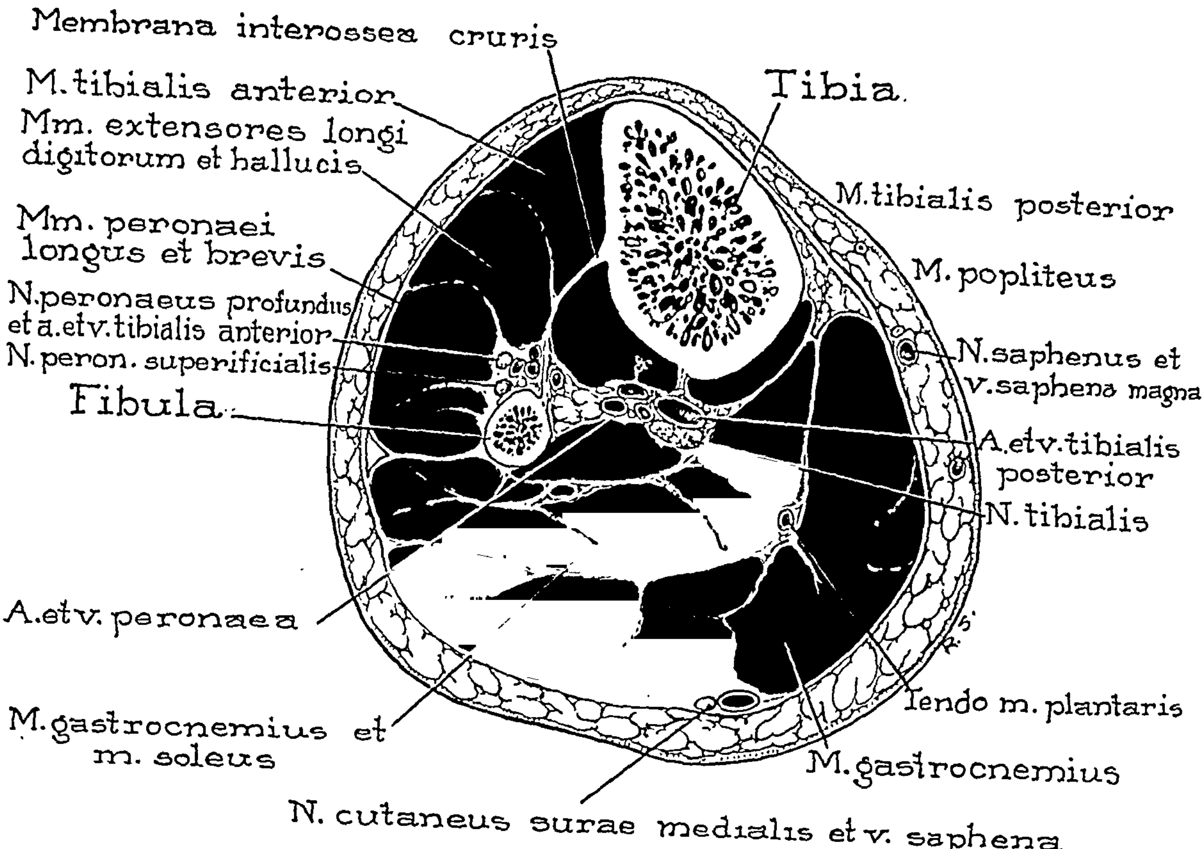

FIG. 5

Cross section of the leg at the level just inferior to the formation of the peroneal artery. (*Redrawn from A Cross-Section Anatomy by Eycleshymer and Schoemaker, and reproduced by courtesy of D. Appleton-Century Company.*)

from exhaustion, may precipitate the onset of severe ischaemia by compressing those arterial channels still remaining open.

ANATOMY

The muscles of the anterior fascial compartment of the leg are particularly vulnerable to circulatory disturbances, because of the relatively rigid walls of the compartment. Figures 4 and 5 demonstrate the relationship of the anterior fascial compartment. The compartment is bounded anteriorly by the fascia cruris, which fuses intimately with the periosteum of the tibia medially. The posterior wall is composed of the dense interosseous membrane, the fibula, and the posterior fibular intermuscular septum. This septum fuses laterally with the fascia cruris to complete the compartment. The anterior fibular intermuscular septum exists only in the upper third of the leg, and does not form a complete compartment. The fascia cruris closes the compartment superiorly, where it is continuous with the fascia lata closely surrounding the knee, and inferiorly, where it is thickened as the transverse crural ligament at the ankle. Both branches of the common peroneal nerve enter the compartment. The opening in the interosseous membrane for the entrance of the anterior tibial vessels into the anterior fascial compartment can be clearly seen in Figure 4. This aperture is adequate, so that no impairment of circulation could occur at this site.

TREATMENT

Patients having only mild manifestations of the disease have been treated expectantly with bed rest, elevation of the affected parts, splinting, and analgesics. Those patients having more marked findings have been treated by procaine block of the lumbar sympathetic ganglia, and by surgery. Block of the lumbar sympathetic ganglia may not be adequate, if segmental arterial spasm persists, due to a distal reflex arc, as suggested by Foisie, or where arterial occlusion has occurred.

Surgical treatment includes extensive fasciotomy of the anterior fascia cruris, and, in certain cases, when indicated, arteriectomy of the anterior tibial artery. Fasciotomy was sufficient to allow return of circulation in one leg of a patient having bilateral involvement.[13] Fasciotomy did not adequately improve the circulation in either of the cases reported here, but it did relieve the pressure on the branches of the common peroneal nerve, and allow their return of function in Case 2.

Arteriectomy should be performed, if pulsation does not return in the anterior tibial artery. This procedure, advocated by Leriche, has been recommended recently by Griffiths and by Foisie in the treatment of acute Volkmann's ischaemia.

Leriche believes that the obliterated artery becomes a diseased sympathetic nerve, inducing vasoconstriction in the collateral network. He has demonstrated the increase in collateral circulation following resection of the diseased artery. He reported a series of sixty cases of varied types of arterial disease, involving seventy-eight arteriectomies. There was definite relief of symptoms in 43.6 per cent. of all cases described. The greatest percentage of relief occurred in the traumatic cases, where relief was obtained in 66 per cent.

It may, therefore, be concluded that arteriectomy should be strongly considered as a therapeutic procedure in all cases demonstrating serious involvement of the anterior tibial artery.

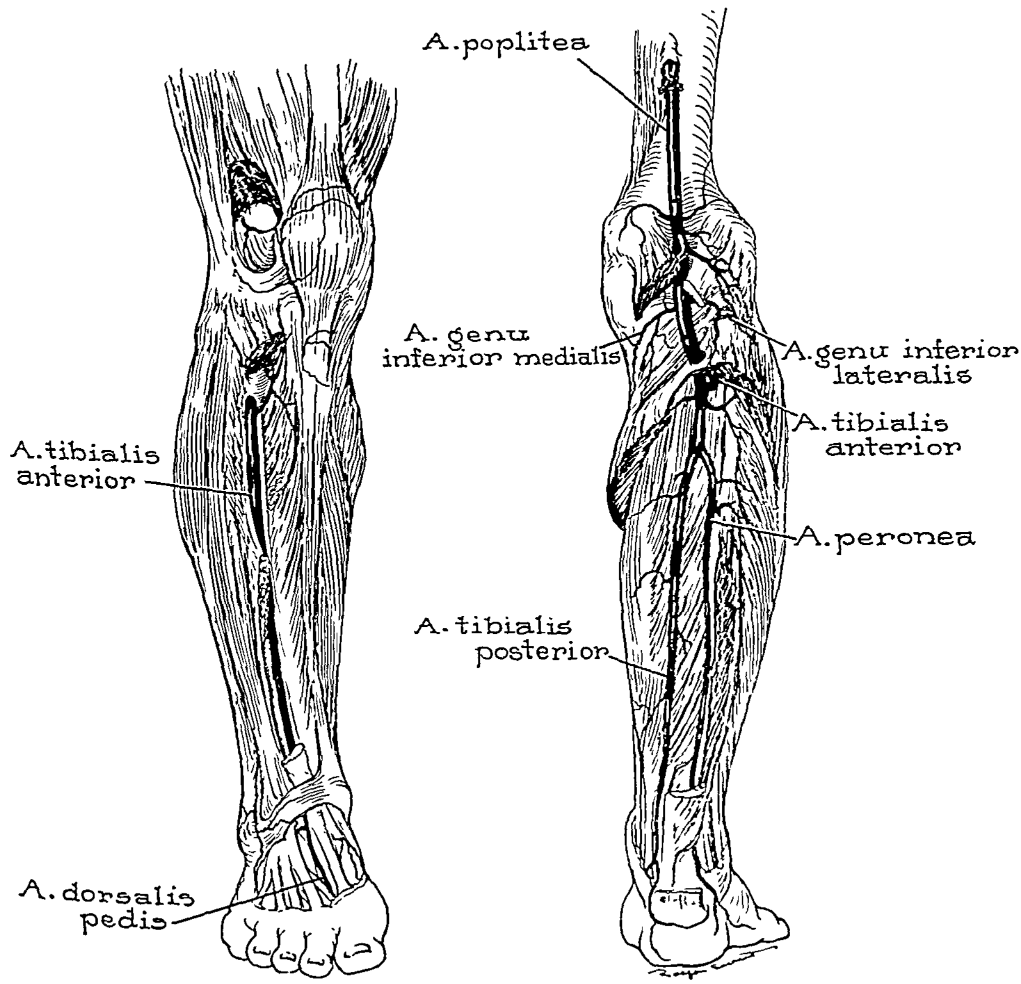

Fig. 6

Arteries of the leg. (*Redrawn from Hand Atlas of Human Anatomy by Spalteholz, and reproduced by courtesy of J. B. Lippincott Company.*)

CONCLUSIONS

1. The syndrome of localized ischaemia of the anterior tibial muscle and long extensor muscles of the toes presents a definite entity.

2. The essential vascular change is a fibrosis of the media, adventitia, and periarterial tissue of the anterior tibial artery, with ensuing occlusion.

3. The histological changes in the affected muscles are identical to those occurring in Volkmann's ischaemia.

4. The pathogenesis is obscure, but may be explained by repeated overwhelming physiological demands upon the anterior tibial artery, such as occur in long periods of training in the infantry, and in athletics.

5. The acute onset of severe ischaemia during marching is probably due to muscular exhaustion, and swelling in the anterior fascial compartment.

6. The musculature of the anterior fascial compartment is particularly vulnerable to circulatory disturbances, because of the anatomical arrangement.

7. Early block of the lumbar sympathetic ganglia and early complete vertical incision of the anterior fascia cruris improve the collateral circulation, and permit the return of function to the common peroneal nerve.

8. Arteriectomy is indicated, if segmental arterial spasm persists or if arterial occlusion is present.

9. Idiopathic claw-foot may be the result of insufficiency of the anterior tibial artery with ischaemic contracture of the anterior tibial muscle and long extensor muscle of the toes.

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SEVERE WAR INJURIES OF THE ELBOW*

BY MAJOR SPENCER T. SNEDECOR AND MAJOR WALTER C. GRAHAM

Medical Corps, Army of the United States

Experience on the Orthopaedic Service at the Valley Forge General Hospital has given a fair perspective on how to meet the problems of severe elbow fractures as they occur in war casualties, in the various theaters of war.

First of all, it has been found necessary for purposes of analysis to make a thorough objective examination of each patient's injury. The study should cover the complete history of the patient: how, when, and where he was wounded; what his initial treatment was; and what had been his intermediate care. Usually all of the patient's roentgenograms accompany him. As soon as convenient, new roentgenograms are taken without the plaster casts, to show the complete detail of structural derangements. The following points covered in the examination call attention to the special nature of these injuries.

1. *Nerves:* Is there any paralysis? The first check is the motor and sensory response of the ulna, the medial, and the radial nerves, because so often in shattering compound injuries about the elbow one or more of the major nerves are involved.

2. *Blood Vessels:* Three cases of obliteration of the brachial artery have shown the seriousness of circulatory complications. In two of them severe contractures of the hand and wrist followed the resulting ischaemia.

3. *Muscles:* Partial tears of many of the muscles are common and not too serious, unless innervation has been damaged.

4. *The Joint:* Each case is considered not as a simple fracture, but as a badly comminuted and disorganized elbow joint. Yet, with conservative support and protection, it is amazing to see fragments of bone and periosteum coalesce, and resolve into strong healthy bone. Gradually the joint itself regains form and detail. In the final stages of healing, motion and even active use may be permitted to determine the residual factors which must be met. Is there hinge action? Is there any rotation? What fragments are missing? Which distortion causes a block of flexion or extension? Is there non-union? Each case may present numerous and intricate abnormalities of the joint structure. For these reasons the general management of the bone comminution must be definitely conservative.

FUNCTIONAL OBJECTIVES

One must carefully analyze the residual or prospective joint function according to the following precepts:

1. *Strength:* Experience with patients gives the impression that the most desirable objective is a stable elbow to strengthen the forearm and hand. To obtain this a fixed elbow is far better than a painful or a flail elbow.

2. *Range of Motion:* If an elbow must become fixed, it will be most useful to a man doing heavy work, for example, to have it fixed at an angle of 110 to 120 degrees. A range of from 70 to 120 degrees of flexion and extension, with 50 per cent. of normal pronation and supination, gives a useful elbow.

INTERMEDIATE TREATMENT

Following this objective analysis of the problem, a plan of treatment can be laid out for the patient, and the various steps can be visualized. Each one of the following phases must be cared for in turn:

* Presented at the meeting of the Orthopaedic Club of Philadelphia at Valley Forge General Hospital, October 13, 1944.

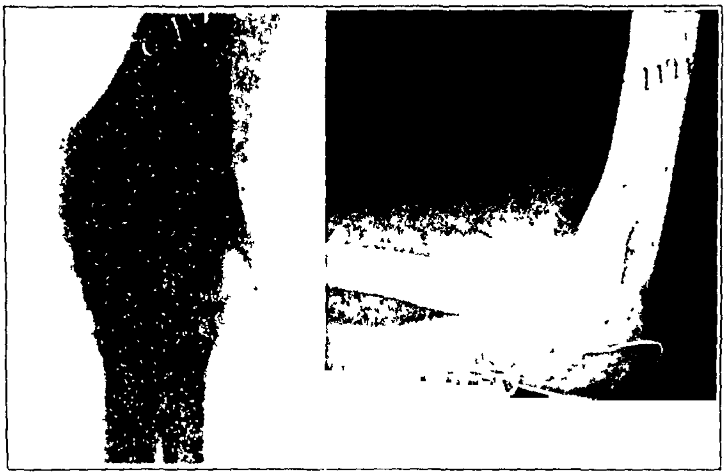

FIG. 1-A

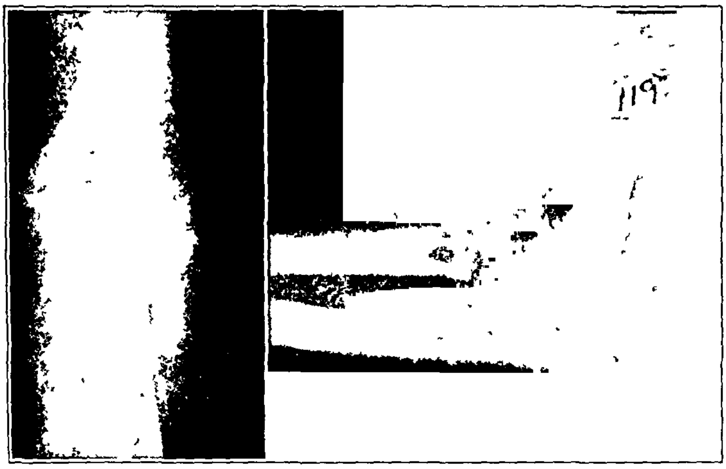

FIG. 1-B

Case 1. Injury occurred in Tunisia, January 1943, in collision of truck and half-track.

Fig. 1-A: Roentgenogram at time of admission, showing healed fractures of head of radius, external epicondyle, and olecranon. Rotation of only 20 degrees in pronation; flexion to 90 degrees; extension of 130 degrees.

Fig. 1-B: Postoperative roentgenogram, following removal of wire around olecranon, excision of head of radius, and projection of external epicondyle. Rotation 70 per cent. of normal; flexion to 75 degrees; extension to 150 degrees.

At the beginning, the open wounds must be carefully dressed. If the wound is deep, and bony instability is a strong factor, it is advisable to use plaster dressings for a time. As a matter of fact, most of the cases arrive from overseas in plaster casts. Plaster has its advantages: for transportation, for rest of the injured part, for support to the circulation, and for control of the bone fragments. However, the plaster is removed as early as practical. Soft-tissue healing takes place faster outside of plaster, and early mobilization of the elbow can also be carried out to advantage. Exposed bone must be trimmed back so that granulations will spread over it. Sequestra, if they are causing persistent sinuses, must be removed.

RECONSTRUCTIVE SURGERY

Reconstructive surgery on elbow joints must not be undertaken too soon. Not only must the danger of infection have passed, but also all active tissue reaction must have subsided before any operative procedure can be assured of success. The use of penicillin, before and after operation, greatly decreases the chance of infection, and permits much earlier operative intervention. Nevertheless, the postoperative proliferation of fibrous tissue, the thickening of the capsule, and the progressive phase of myositis ossificans are the dangers to be avoided by waiting until months have passed.

The best way for us to analyze the possibilities for reconstruction of an elbow joint is to follow down along anatomical lines:

A. *Epicondyles of the Humerus:* The epicondyles have little significance in severely deranged elbows. If they are destroyed, the muscle origins will re-attach themselves to the bone and fascia, and continue to function properly. In time they may regrow. Many spurs of bizarre appearance will form on the condyles as the muscle origins, which have been torn loose, become re-attached to the bone. Whenever these spurs seem to interfere with function, they are removed, as in Case 1, without any subsequent weakness of the extensors.

B. *External Condyle:* Here, function is checked by a bony block. The most common type of severe fracture of the external condyle results in rotation, and, usually, forward displacement of the capitellum in varying degree. The functional loss is limitation of flexion and extension, because of blocking by the radial head. Rotation is often nearly normal. Nevertheless, if the flexion block is beyond 90 degrees, it may be wise to resect the radial head; a decided gain in flexion will follow. The capitellum may be reshaped at times by removing the anterior deformity.

A most instructive case was one in which the external condyle was entirely missing (Case 2). Yet, this soldier had a strong, painless, and useful arm with flexion to 75 degrees, extension to 140 degrees, and complete rotation. His wrist and hand extensors worked normally, although no bony origin for the muscles could be demonstrated. Apparently, the extensor muscles attached themselves to the fascia and scar tissue leading to the shaft of the humerus. In retrospect, serious thought has been given to the relative importance of the entire external condyle. Apparently as long as enough of the trochlea remains to give stability to the swing of the olecranon, the outer condyle is not essential. Noteworthy in these cases is the fact that rotation is complete.

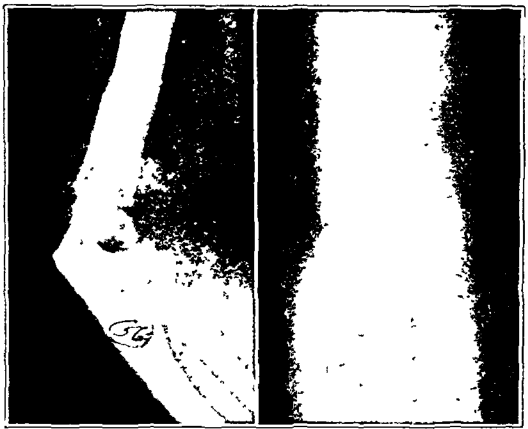

FIG. 2

Case 2. Soldier wounded in Italy, in January 1944, by machine-gun bullet. Final stage of bone healing, with external condyle and capitellum completely missing, yet functional result excellent. Strong, stable elbow. Rotation complete; flexion to 75 degrees; extension to 140 degrees.

C. *Internal Condyle:* The internal condyle may be fractured as often as the external, but the final results are quite different. The joint between the condyle and the olecranon may be so destroyed that eventual spontaneous fusion will take place. With this anticipated outcome, care must be taken to preserve the joint angle for greatest usefulness. Case 3 illustrates this point. The boy had a fixed olecranon, but retained complete rotation. He left the hospital with a strong right arm, and with every anticipation of resuming his occupation as a stable groom. In other cases, as in Case 4, a fair amount of motion may be preserved, even though considerable deformity results. This soldier's flexion range was from 70 degrees to 135 degrees, while the radial head remained free, and rotated normally. The result was quite satisfactory from the viewpoint of function. Such reconstructive surgery as can be performed on the inner side of the elbow is limited at this stage, but later an arthroplasty may be done.

D. *Olecranon:* The hinge action of the elbow will function with very little of the olecranon. As long as the triceps attachment is preserved, it has stability, and functions very well. In comminuted fractures of the proximal olecranon, it is advantageous to discard the fragments. In two cases the olecranon was considerably shortened, with excellent functional results.

In a number of cases the olecranal fossa was distorted and was filled with callus. Reshaping the fossa has not resulted in as much extension as was anticipated, possibly because sufficient bone was not removed. In retrospect, the writers would prefer to shorten the olecranon by as much as one-third to one-half of its proximal end, where it blocks extension. The triceps tendon would be re-attached after subperiosteal reflection. Instability of the joint will not follow. Fragments of the coronoid process of the olecranon may also be removed without the joint slipping backward in extension.

E. *Radial Head:* Loss of full rotation is the common result of comminuted or displaced fractures of the head of the radius. Experience with corrective surgery for these rotation handicaps has been quite satisfactory. Resection of the head of the radius will nearly always give 50 to 85 per cent. of the normal range (Case 1). Two patients lost the upper radius down below the bicipital tubercle without any serious impairment of function of the biceps. The attachment to the ulnar aponeurosis continued. The writers' follow-up has not been long enough to discover how many painful radio-ulnar joints develop after resection of the head of the radius. Removal of the distal end of the ulna has been a satisfactory correction for this complication in several painful radio-ulnar joints resulting from other injuries.

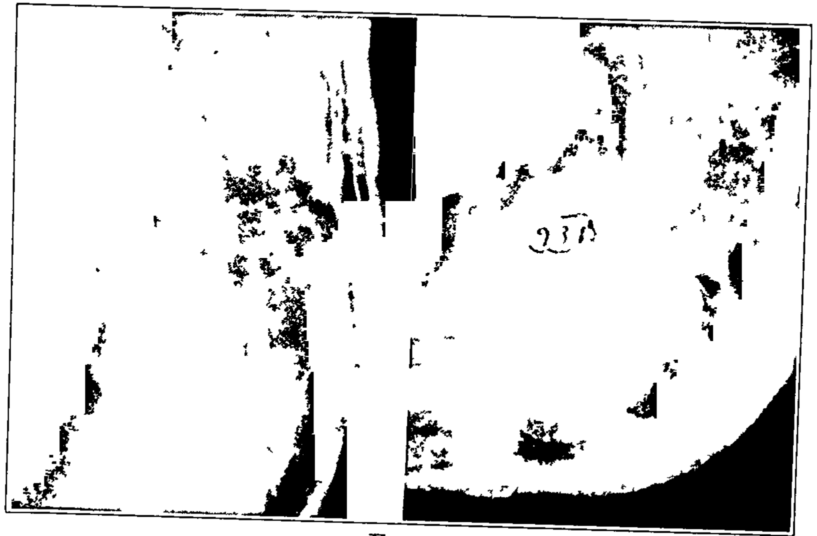

Fig. 3-A

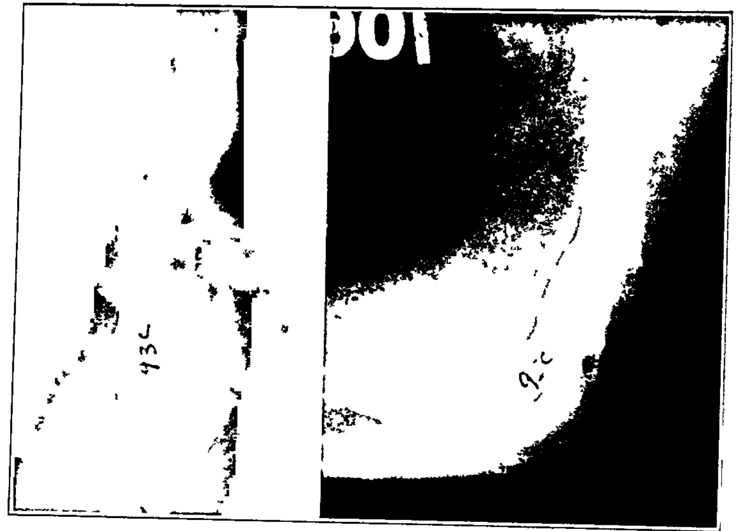

Fig. 3-B

Case 3 Soldier wounded in Africa by machine-gun fire, March 1943.
Fig. 3-A: Shattered elbow shown in cast on arrival in this country. Sequestrectomies in August and September 1943.
Fig. 3-B: January 1944, final bone healing, showing bony ankylosis between olecranon and trochlea. Rotation normal.

Fig. 4-A

Fig. 4-B

Case 4. Wound occurred in Italy, from machine-gun fire, January 1944
Fig. 4-A: Comminuted condyles of humerus on arrival in this country.
Fig. 4-B: Final healing of distorted condyles. Rotation complete

FIG. 5-A FIG 5-B

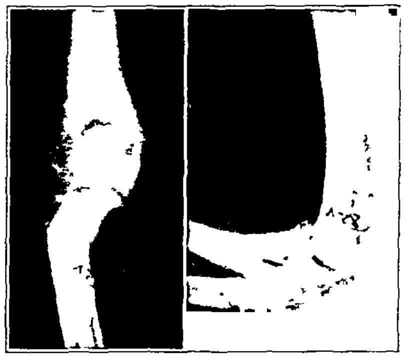

FIG 6

Case 5. Soldier injured in truck accident in Italy, February 1944.

Fig. 5-A: Dislocation of elbow with fracture of the head of the radius, which was excised overseas.

Fig. 5-B: Myositis ossificans, scar tissue, and contracture of anterior capsule which restricted extension to 90 degrees. Flexion and rotation practically complete; 50 degrees of extension was gained by anterior capsulectomy.

Case 6. Soldier struck by propeller of plane, June 1943, in Libya Synostosis between proximal radius and ulna following fracture of ulna. Rotation of 75 per cent. regained after excision of bony bridge.

F. *Anterior-Capsule Block:* This clinical entity arises from thickening and contracture of the anterior capsule of the elbow joint, with or without the deposition of calcium or the presence of bone fragments from the coronoid process of the ulna or the head of the radius. Usually the brachialis muscle has been lacerated and replaced by fibrous tissue, or myositis ossificans has developed. These cases are quite common after the usual dislocations of the elbow, as well as after the severely comminuted fractures seen by the writers. The functional handicap here is loss of extension. A satisfactory operative correction for this may be performed after a safe period has elapsed in which to allow all tissue reaction to subside. Resection of the anterior capsule of the joint, along with removal of scar tissue and bony masses, will ensure a reasonable improvement in extension. Postoperatively, these patients should wear splints, and the elbow should be in extension for three weeks. After that time, a night splint should be worn in order to prevent any tendency toward recurrence. In Case 5 there was a gain of 50 degrees by operation, a range of 70 to 140 degrees.

G. *Synostoses:* These may occur between the radius and the ulna near the joint. Resection of these bony bridges must be done carefully and thoroughly. Soft tissue must

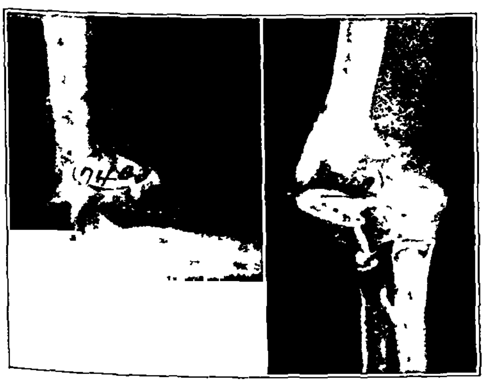

FIG 7-A

FIG. 7-B

Case 7. Wound was caused by shell fragments, in Tunisia, March 1943

Fig. 7-A: False joint in supracondylar region, after soft-tissue healing, was weak and unstable.

Fig. 7-B: Realignment with fibrous union that permitted 10 degrees of motion; an additional 10 degrees of motion remained in the true joint. Rotation in true joint complete. Arm now strong and stable.

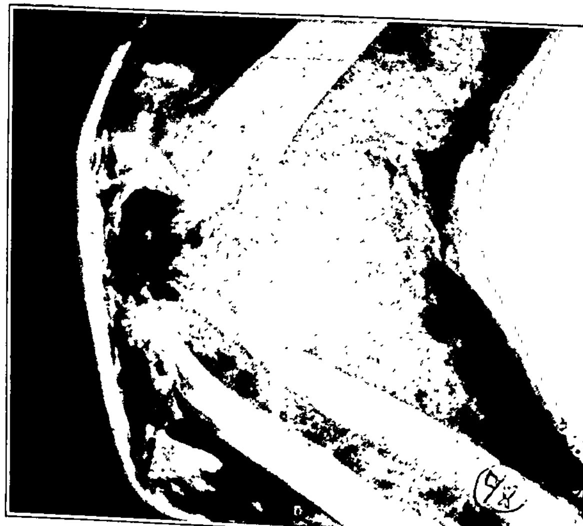

Fig. 8-A

Fig. 8-B

Fig. 8-C

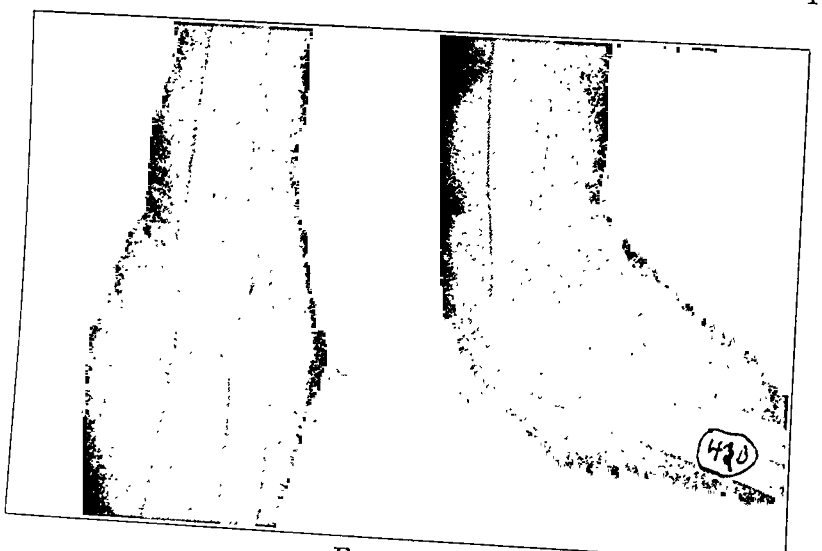

Fig. 8-D

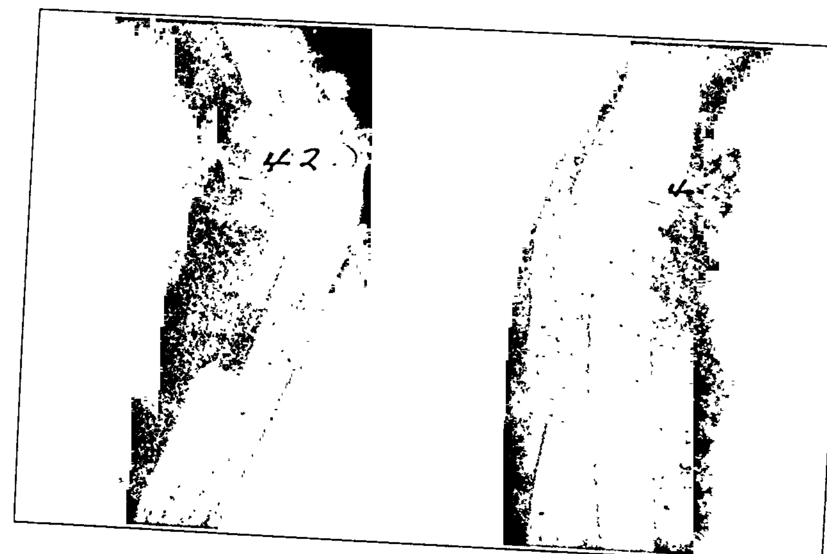

Fig. 8-E

Case 8. Soldier wounded in Tunisia, by rifle fire, May 1943.
Fig. 8-A: "Blasted" elbow on arrival. Radial nerve gone. Fig. 8-B: Flail joint after soft-tissue healing.
Fig. 8-C: Full-thickness skin flap grafted from abdomen. Then the wrist flexors were transferred into the thumb and finger extensors.
Fig. 8-D: Reposition of all three bone ends for the purpose of fusion.
Fig. 8-E: Final operation: resection of proximal radius to permit rotation. Result: strong, stable elbow with motion from 100 to 120 degrees; rotation 70 per cent. of normal; strong, useful hand with full range of function.

always be interposed to prevent their recurrence. One patient (Case 6) regained two-thirds of normal rotation. Case 8 represents a different problem, but this was solved by resecting one inch of the proximal radius; at least two-thirds of normal rotation returned.

H. *Pseudarthrosis:* This supracondylar false joint, as shown in Case 7, produced a weak, awkward action of the elbow and the hand. At operation the old bone was removed, and the fragments were replaced in relatively normal alignment, and fixed with Kirschner wires. The hoped-for union failed, probably because of the development of a low-grade infection, but the pseudarthrosis stabilized very well, with only 10 degrees of painless motion. Ten degrees of motion also remained in the elbow joint. The final analysis was: rotation complete and painless; flexion from 80 to 100 degrees with good strength. This is considered preferable to a fixed joint.

I. *Flail Joint:* What to do in case of a "blasted" elbow was solved in Case 8. During the healing of the deep wound, stability was maintained by plaster fixation. As soon as clean granulation tissue had filled in the gap, a split-thickness skin graft was applied to cover the wound. Later the plastic surgeons removed this and substituted a full-thickness abdominal flap. In due time this permitted an extensive operation to clean out the mass of scar tissue and odd bone fragments where the joint had been, and to align the radial and ulnar ends against the humerus. While firm fusion was not obtained, stability was. About 10 degrees of motion persisted, but the arm had good strength without pain. The rotation which had been lost by synostoses was restored successfully by resecting an inch of the proximal radius. It should be noted that the flexor group of forearm muscles functioned with excellent strength, even though both condyles of the humerus were missing.

J. *Unstable Elbow from Non-Union of Proximal Ulna:* Disruption of ulnar continuity near the joint definitely results in the serious handicap of instability.

Fig. 9-A

Fig. 9-B

Fig. 9-C

Case 9. Soldier, wounded in Sicily by machine-gun fire, in July 1943.

Fig. 9-A: Complete excision of deep scar over upper ulna; area covered by shifting full-thickness local flap. Residual scar was covered by free split-thickness graft from thigh.

Fig. 9-B: Showing defect in ulna, with angulation and rotation of olecranon.

Fig. 9-C: Application of fibular graft; proximal end doweled and fitted as intramedullary graft; distal end "stepped" against shaft and held by two screws with nuts and washers.

While the radius serves as a guide in forward and backward motion, it acts simply as a pivot on which the forearm twists laterally when the ulna is missing. Case 9 illustrates this condition clearly. Before a bone graft could be attempted, the rotation had to be corrected by means of a series of casts, in order to realign the olecranon with the rest of the shaft.

K. *Paralyses:* Patients have been treated for persistent loss of muscle function due to injuries to the nerve in the elbow region, including the ulnar, the median, and the radial nerves. Tendon transplants for radial paralysis give excellent results. In a number of cases, the same basic muscle-transfer operation with minor variations was performed. A typical example was Case 8, where the patient's elbow joint was "blasted" out, and there was a five-inch gap in the radial nerve, which caused a paralysis of all the extensor group. Here the flexor carpi ulnaris and flexor carpi radialis were transplanted into the extensor tendons of the fingers and thumb. There is little problem with re-education. Simple occupational therapy will develop the new coordinating action of the muscles.

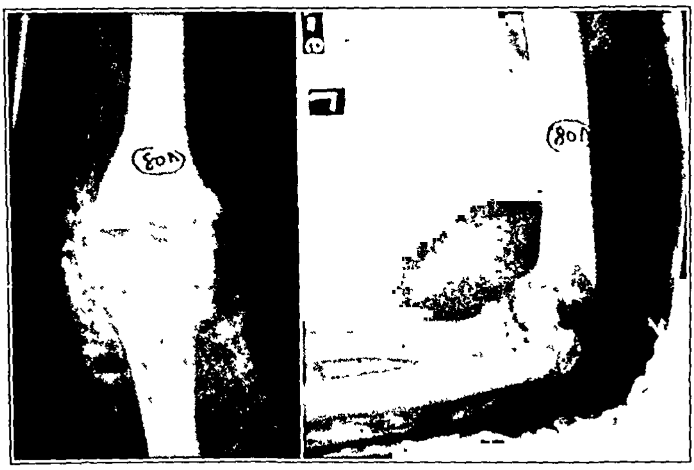

FIG. 10-A

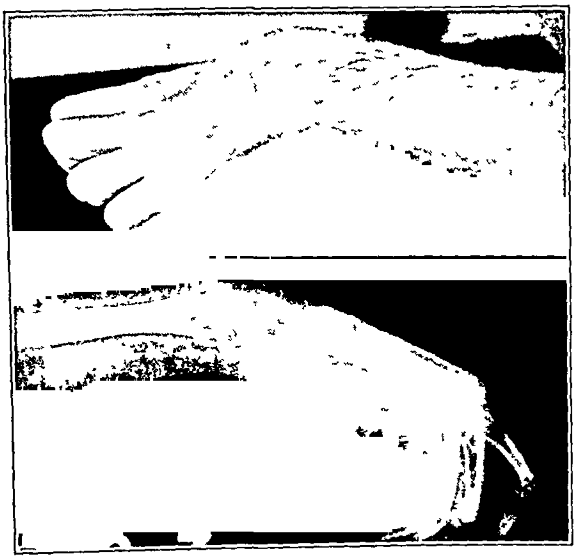

FIG. 10-B

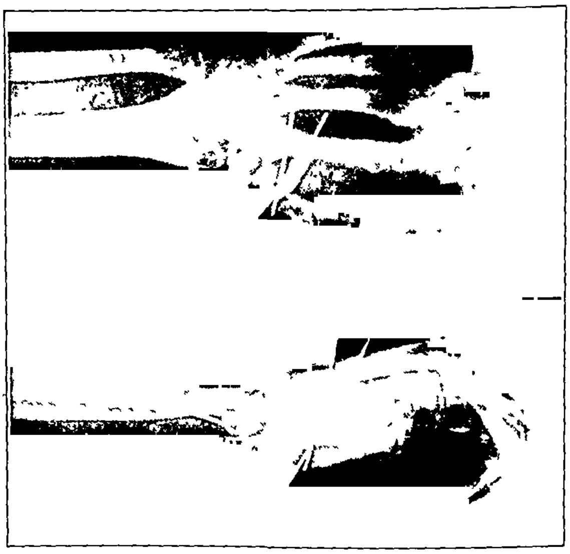

FIG. 10-C

Case 10. Soldier, wounded by shell fragment, in Algiers, in June 1943.

Fig. 10-A: Perforating wound of elbow which destroyed brachial artery, as well as fracturing internal condyle.

Fig. 10-B: Severe flexion contracture (Volkmann type), following ischaemia of forearm. Very little muscle power.

Fig. 10-C: At carpectomy (upper roentgenogram), radius was fused to second, third, and fourth metacarpals by sliding bone graft. At final operation, bone block was inserted between the first and second metacarpals to hold the thumb out for opponens action. Result: improved position of hand in relation to forearm (lower roentgenogram).

L. *Ischaemic Contractures:* To complete the discussion of elbow problems, two cases of severe muscle destruction and contracture should be included. These followed gunshot wounds about the elbow, which involved the brachial artery, and resulted in a severe contracture of the wrist and hand. After months of painstaking stretching and training of fingers and wrist, a carpectomy, with arthrodesis from the radius to the metacarpals, was required in each case. The result was well worth the effort, for the hand was brought into

a good grasping position and the tendons were loose enough so that the little strength which remained in the muscles could be used to good advantage.

CONCLUSIONS

As a result of our experience with a fairly extensive series of severe war injuries to the elbow joint, several guiding principles can be offered.

1. A careful objective examination of each patient must cover nerves, blood vessels, muscles, joints, and bones.
2. Healing of the wounds must first be obtained, the optimum position for stability and function, and the importance of preserving motion whenever possible always being kept in mind.
3. Early splint-thickness skin grafts are often needed to cover granulating surfaces. Later, full-thickness flaps may be substituted, to replace scar tissue and to permit reconstructive surgery.
4. Removal of all exuberant bony masses around the elbow is an aid in promoting function.
5. Surgery should be performed step by step, after it is ascertained each time that all tissue reaction has subsided, and the results of previous steps have been appraised. Conservatism is well rewarded, on the whole, for nature performs remarkable recoveries.
6. For each anatomical displacement about the elbow, a special type of reconstructive surgery is indicated.
7. Much of the normal elbow structure—such as the olecranon, the coronoid, the external condyle, and the head of the radius—may be lost or removed in individual cases without too seriously affecting function.
8. A careful follow-up program of physical and occupational therapy is necessary to obtain good results.
9. The primary measure of usefulness of an injured elbow is stability, so that the forearm and hand may have strength. A moderate range of motion, including rotation of the forearm, provides added basic usefulness.

DUAL PLATES FOR INTERNAL FIXATION IN NON-UNION OF FRACTURES

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Last Fall the writer was consulted by a patient with flail pseudarthrosis of the humerus of eight years' duration, with a relatively short distal fragment. The patient had only one leg, the other having been amputated at the time of the injury to the arm. However, he walked so well on his artificial leg that the disability was not noticeable.

Since two patients from whom massive grafts had been removed had suffered fractures of the donor leg some three months after the operation, some hesitation was felt in removing dual grafts from the patient's only leg, so he was sent home until another procedure could be decided upon.

In view of past experience with stainless-steel bone plates used in combination with Steele's barrel-stave grafts or Abbott's iliac grafts,[3] it seemed that dual bone plates, supplemented by iliac grafts, might achieve the desired result. Consequently, a series of paired bone plates, one of each pair being threaded for the standard bone screws, was designed. Since Murray had emphasized the necessity of fixing the fragments in two planes in order to obtain rigid internal fixation, one group of plates was designed with a curved arm, projecting from each end and in opposite directions to provide for screws at right angles to those in the body of the plate. The others were ordinary steel plates, half of which were standard, and in the others the screw holes were small and threaded.

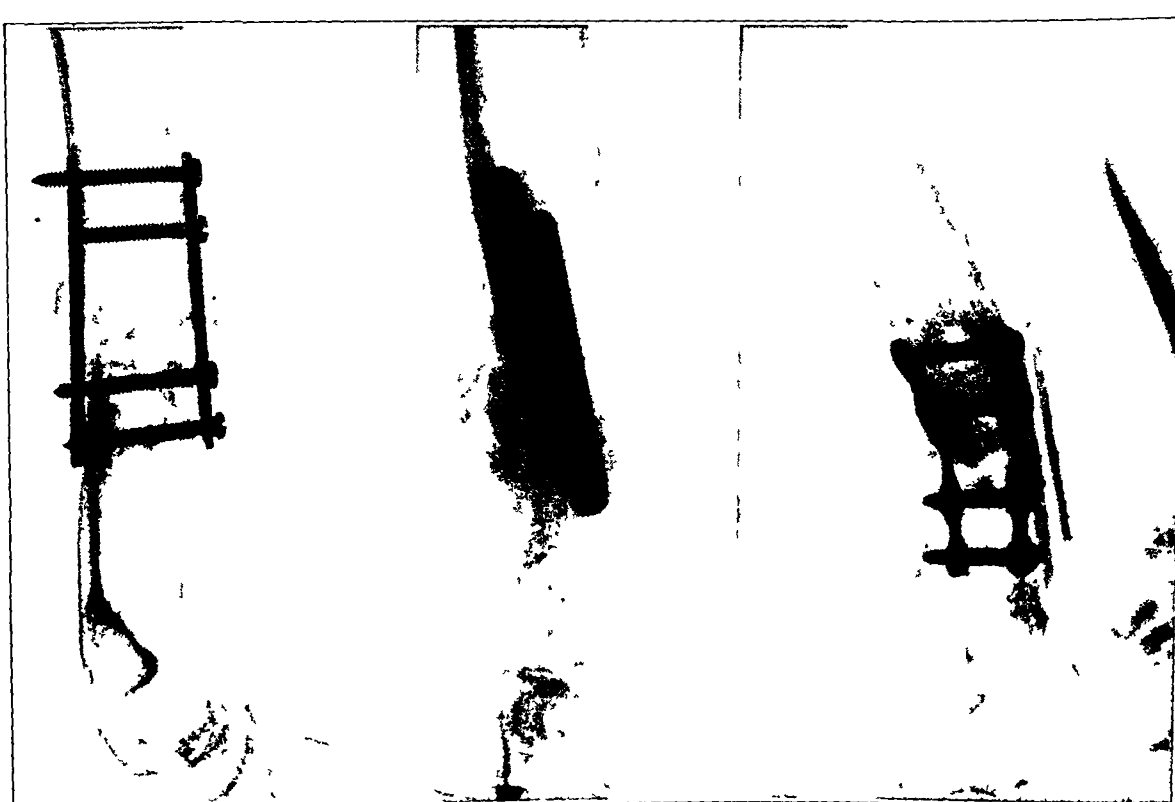

FIG. 1-A FIG. 1-B FIG. 1-C

Dual plates applied to two old ununited fractures of the humerus.
Fig. 1-A and Fig. 1-B show the plates supplemented by iliac grafts.
Fig. 1-C shows barrel-stave grafts; this humerus was purposely angulated to improve the position of the stiff elbow.

At the first operation, on an ununited and deformed femur, it was soon found that the application of the plates with the curved side arm was too difficult a procedure to be practical. Therefore, the ordinary straight plates were used, and even in the application of these, an unforeseen problem arose when it was attempted to insert the second screw. It was necessary to so drill the hole that the drill point would emerge exactly opposite the hole in the plate on the far side of the bone, and stop before it spoiled the thread in the plate. However, the difficulty was partly solved by using a small drill, which was drilled through each inaccessible and invisible hole in the threaded plate on the deep aspect of the bone. The hole was then enlarged to permit free passage of the screws through the bone. Although the threads in the last hole in the deep plate were destroyed by the drill (Fig. 1), even without this sixth screw the rigidity obtained when all of the screws were tightened was amazing. The plates acted as clamps and fixed the bones rigidly, permitting no movement in any direction.

A drill guide was at once designed, which is now available commercially, in order to make the application of the plates a practical surgical operation. It consists of a modified S-curved metal bar with a button on one end to fit into the threaded hole in the deep plate. The third at the middle of the bar is straight, and on this there is placed a guide which fits a drill (nine sixty-fourths of an inch). This guide slides up and down, and is provided with a set screw which locks the tubelike guide against the hole in the superficial plate. A drill passed through the guide strikes against the button, thus ensuring correct position of each drill hole.

In applying the dual plates, the site of the fracture is exposed through a relatively long incision, in order that with retraction two sides of the ends of the fragments can be exposed. The fracture is then reduced, and held with bone forceps, while suitable plates are selected and placed in position. If necessary, the exposed surface of the bone can be shaved or grooved with a chisel to provide a suitable bed for the superficial plate.

When the superficial plate is in place, a single hole is made straight through the bone with the drill. This hole should be made at the most inaccessible end of the plate, and should pass through the hole in the superficial plate, and emerge from the bone in the area to be occupied by the deep plate. The deep plate is then placed in position, and a screw of suitable length is passed through the end hole of the superficial plate and the bone, and is engaged in the threaded hole in the deep plate. The ends of the two plates are screwed together, but not very tightly.

After the fracture has been reduced and the plates have been applied in the desired position, the button on the end of the guide is then placed in one of the threaded holes in the deep plate, the guide sleeve is slipped down into the larger hole in the superficial plate, and the set screw on the guide is tightened to hold it in place. Then the drill (nine sixty-fourths of an inch) is passed through the sleeve and drilled through the bone until it contacts the but-

Fig 2
Old supramalleolar fracture of the leg, fixed by dual plates plus a free (Phemister) graft on the posterior surface of the leg

FIG. 3
Old fracture of the femur, fixed by dual plates, supplemented by barrel-stave grafts.

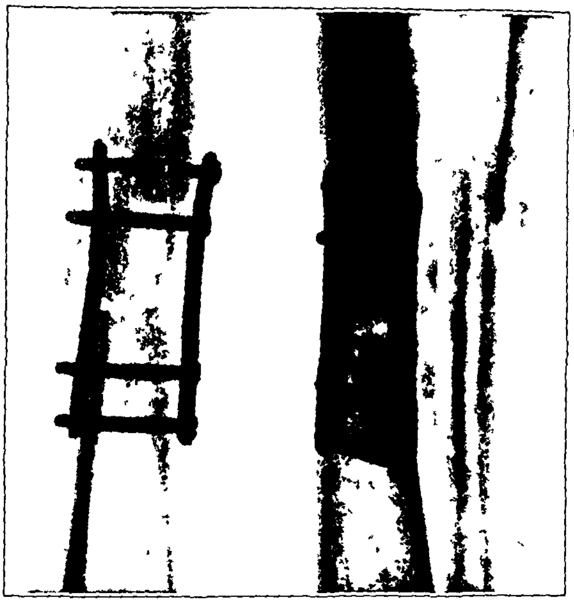

FIG. 4
Old fracture of the tibia, fixed by dual plates, supplemented by iliac grafts.

ton in the hole in the deep plate. The guide is then removed, and a screw of suitable length is inserted and tightened to a moderate degree.

The other screw holes are then treated in the same manner, and, finally, when all of the screws are in place, they are tightened to clamp the bones firmly together. The wound is then closed in the usual manner.

If one is dealing with non-union, the ends of the bones may be freshened, or revised, or subjected to multiple drilling as indicated, and the fracture site should be crossed by a free, short onlay graft of the Phemister type, or by the multiple barrel-stave grafts of Steele, or the iliac grafts of Abbott. These are supplemented by packing cancellous bone wherever it will do the most good.

The dual plates supplemented by bone grafts, either from the ilium or the tibia, have been used in seven cases of non-union: one femur, two humeri, and four tibiae. In all, satisfactory fixation of the fragments was obtained, and the fractures have united unusually rapidly. The amount of postoperative external fixation has been minimal. The femur was not splinted, and the patient was kept in bed with only a small pillow under the knee. There was no cast, and five pounds of traction was applied. This patient was able to raise his heel on the day after the operation. Four weeks after the operation he went home on crutches, with instructions to exercise the knee. Weight-bearing with a cane was permitted four months after the operation.

The tibiae were fixed in a cylinder cast to the mid-thigh for the first ten days or so, and then the sutures were removed, and a short leg cast was applied for a period of six weeks. Weight-bearing was begun gradually.

The humeri were immobilized in a posterior plaster mold, extending from the upper arm to the wrist, with the elbow flexed about 90 degrees. The wrist was suspended from the neck, and a few days after the operation swinging or pendulum exercises were started, as in the hanging-cast treatment of fractures of the humerus. Four weeks after the operation the plaster mold was removed, and the wrist was supported by a cravat sling. Exercise of the elbow and light use of the arm were permitted. These were increased gradually, and the cravat sling was discarded when the patient felt that it was not needed. The humeri were quite strong in eight weeks.

The dual plates have not yet been used for the fixation of fresh fractures, because a case has not been encountered in which they were indicated. They should be very useful to thoroughly experienced surgeons, provided further use does not disclose contra-indications. There are certain objections to the dual plates:

1. A long incision is necessary, and the bone must be exposed widely. This may necessitate the partial stripping of the periosteum for a distance of two to three inches (5 to 7.5 centimeters). This may be objected to by many, but the writer thinks that such stripping of the periosteum is not apt to delay or prevent union.[3]

2. The operation may be difficult. This is especially true of the tibia, as one plate is placed on the posteromedial and the other on the anterolateral aspect, in order that both may be well covered by soft tissue. It may be necessary to chisel a suitable flat surface on the bone for the reception of each plate, in order that they may lie parallel and grip the bone firmly.

3. If the plates become loose or infected, their removal may be necessary, and this will be more difficult than the removal of a single plate.

FIG 5
Old fracture of the tibia, fixed with dual plates, supplemented by free (Phemister) graft to the tibia. The defect from which the graft was taken is shown in the proximal half of the tibia

4. If possible, application of the dual plates should not be undertaken without a practical drill guide or jig and a full assortment of screws. The illustrations show that the correct length of the screw is too frequently not available. Thus far the projecting screws have caused no trouble, but they may do so, and, therefore, their use should be avoided.

5. The self-threading screws with a channel are not suitable for metal, and occasionally they bind and have to be removed, and another screw substituted. Ordinary machine-threaded screws would be more suitable, and these may be available later, if this method of fixing bones is favorably received by orthopaedic surgeons.

The author has used the dual-plate method only in fractures with non-union and in conjunction with bone grafts. The operation is difficult, and leaving so much metal in the tissues is objectionable. It should be used only by experienced bone surgeons, and only in situations where rigid internal fixation is definitely indicated. It is not proposed as a routine method for the internal fixation of fractures, and its indiscriminate use should be discouraged.

A similar method of internal fixation was used by Breck and Basom in a patient with a fresh fracture of both bones of the leg. They performed open reduction, and applied a vitallium plate in the usual manner, and then placed a second vitallium plate on the opposite cortex of the femur, and fixed this plate with two vitallium bolts with vitallium nuts in the deep aspect of the wound. They controlled the direction of the screw holes by means of a jig which was clamped to the first plate and the bone. They report that the wound healed rapidly, and the patient was able to begin full weight-bearing in six

weeks. Good union was demonstrated three weeks later, and perfect results were obtained.

It is believed that the hitherto unattainable degree of internal fixation afforded by the dual plates makes them useful in properly selected cases and in the hands of a sufficiently skillful surgeon.

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TREATMENT OF UNUNITED FRACTURES OF LONG BONES

A Method Combining Grafting and Internal Fixation *

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Medical Corps, Army of the United States

This paper constitutes a preliminary report on a technique for the treatment of non-union and delayed union in fractures of the long bones, involving the use of a plate for fixation plus iliac bone as graft material. As yet, insufficient time has elapsed for a final report.

Any method purporting to be better than existing methods must of necessity be simple, easy to use, applicable to large groups of patients, not require excessive operating time, and give as good or better end results. The following method seems to meet all of these requirements. The principle of graft material plus internal fixation in itself is not new, for methods using tibial grafts with one or more plates have been advocated in the treatment of malunion.

There is, of course, controversy regarding the relative merits of cortical *versus* iliac bone as graft material. The essence of this controversy seems to be that while bone from the ilium is more readily revascularized and incorporated into the host bone because of its cancellous nature, tibial bone has the distinct advantage of being rigid enough to give good internal fixation to the host bone when fixed to it with screws. It is this quality of tibial bone which is responsible for the evolution of the classical operation for non-union of the femur,—namely, the massive tibial onlay graft. *We feel, however, that what iliac bone lacks in rigidity is more than compensated for by its osteogenic qualities, and the simple addition of a plate imparts the required stability.* The most marked disadvantage of massive tibial bone grafts, aside from their very slow incorporation into the host bone, is the weakening that results from their removal in a patient who already has one extremity that is inadequate. Any surgeon who has used large tibial grafts extensively has had the misfortune of seeing a new fracture in the donor bone. In addition, it will be recalled that the point of maximum stress on any fixation material is at the fracture site, and the incidence of fracture through tibial grafts after implantation is fairly high.

The ilium, on the other hand, can supply large quantities of bone without ill effect on the patient. For femora we have been able to get a single large onlay graft, 2.5×12.5 centimeters (one inch by five inches), which is essentially flat on both cortical surfaces. In addition, numerous sliver and chip grafts are available. This involves removal of a considerable portion of the wing of the ilium, but we have not observed a resulting limp or other untoward effect, even where both iliac crests were used.

In this series of cases, only iliac bone has been used. In fractures of the femur, six months from the date of injury has been accepted as the time indicating non-union, and four months without roentgenographic evidence of callus as the time indicating delayed union. In compound fractures, surgery was not used until six months after cessation of drainage and complete healing of the skin.

One or two points in regard to the mechanics of the procedure should be mentioned. Clay Ray Murray has shown that placement of fixation elements at right angles to each other gives the maximum stability in fracture fixation. The grafts, fixed with two screws, have therefore been placed at right angles to the plate. A full-thickness iliac graft is a rigid piece of bone; and, when fixed by this method, adds materially to the stability of internal fixation. In the instance of the femur, it was first planned to place the plate anteri-

* Presented before the meeting of the Chicago Orthopaedic Society at Vaughan General Hospital, Hines, Illinois, April 13, 1945.

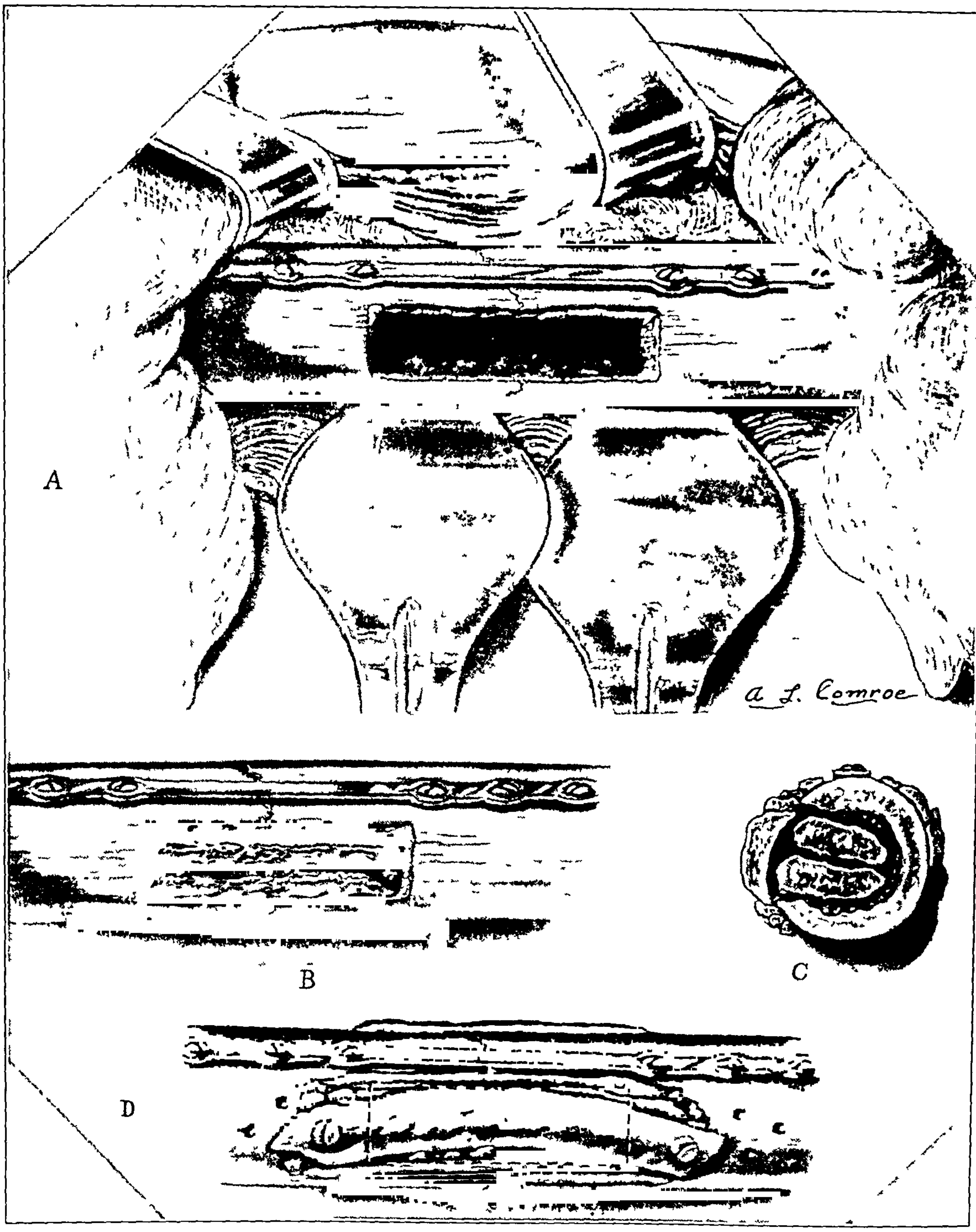

Fig 1

Stages of operative procedure.

A demonstrates the fracture site exposed, and the fragments reduced and well approximated with plate and screws The trough has been prepared to receive the intramedullary grafts shown in place in *B* *D* shows the onlay graft fixed in place, the adjacent sliver grafts and multiple drill holes, while the inset (*C*) demonstrates the relative position of onlay, intramedullary, and extracortical sliver grafts

orly and the graft laterally so that the large mass of the graft might not interfere with the quadriceps mechanism. Lateral platings had already been done in four cases, however, and since the plate should be placed at the point of maximum stress, which is usually lateral, in nine of ten femora the plates were applied laterally and the grafts anteriorly. Apparently the mass of the graft has not interfered with quadriceps function.

It is well known that, following the initial resorption of bone at the fracture site during the first few weeks, a plate often becomes a vicious factor, maintaining the gap at the fracture site and causing non-union by preventing contact of the bone ends This fact

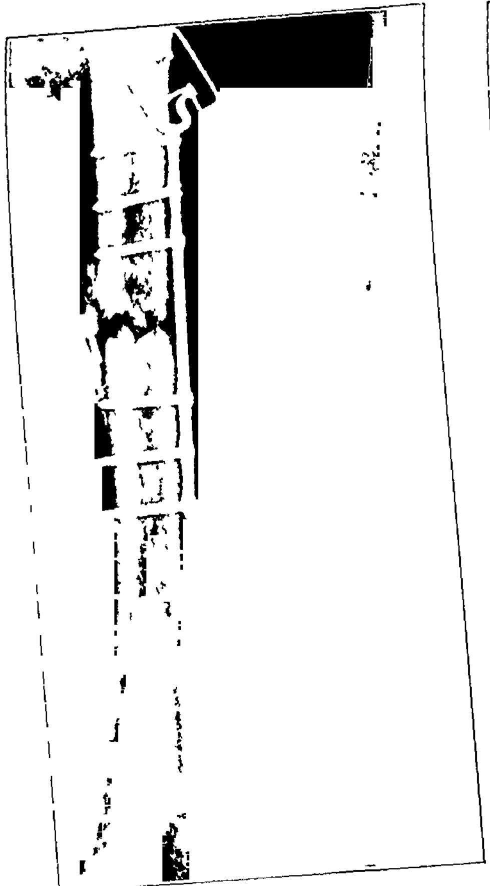

Fig. 2-A

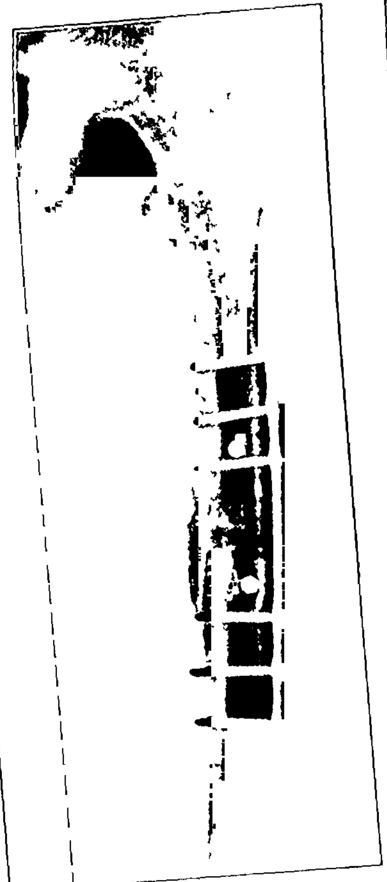

Fig. 2-B

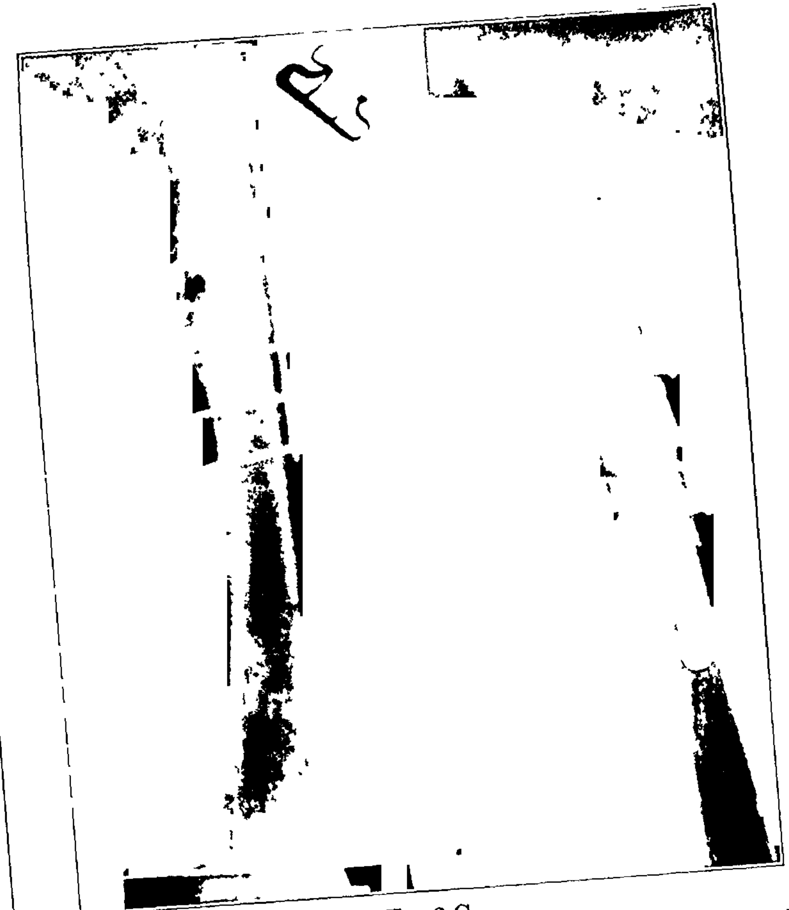

Fig. 2-C

Patient, aged nineteen years, sustained a simple fracture of the femur when he was struck by a falling log. Internal fixation was performed six weeks following injury and prior to return to Zone of Interior.

Fig. 2-A: Roentgenogram showing fracture six months following injury. Note the distraction interval at the fracture site and the small amount of callus that has formed along the medial aspect.

Fig. 2-B: Roentgenogram, immediately following combined iliac bone graft and internal fixation, demonstrates the six-screw plate left *in situ*. The onlay graft has been placed anteriorly and is held by two screws. The intramedullary grafts and multiple drill holes can be seen.

Fig. 2-C: Anteroposterior and lateral views made sixteen weeks later demonstrate the disappearance of the fracture interval, incorporation of the grafts into the host bone, and the firm osseous union. At this stage, the patient was ambulatory, in an ischial weight-bearing brace.

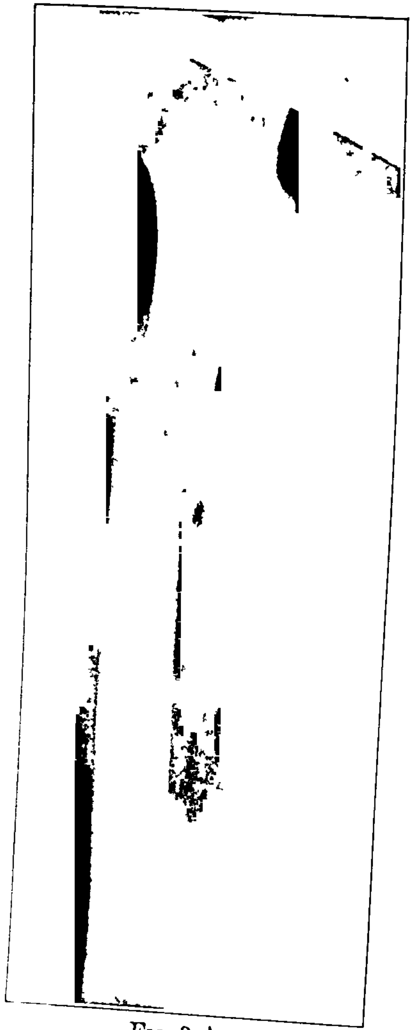

FIG. 3-A

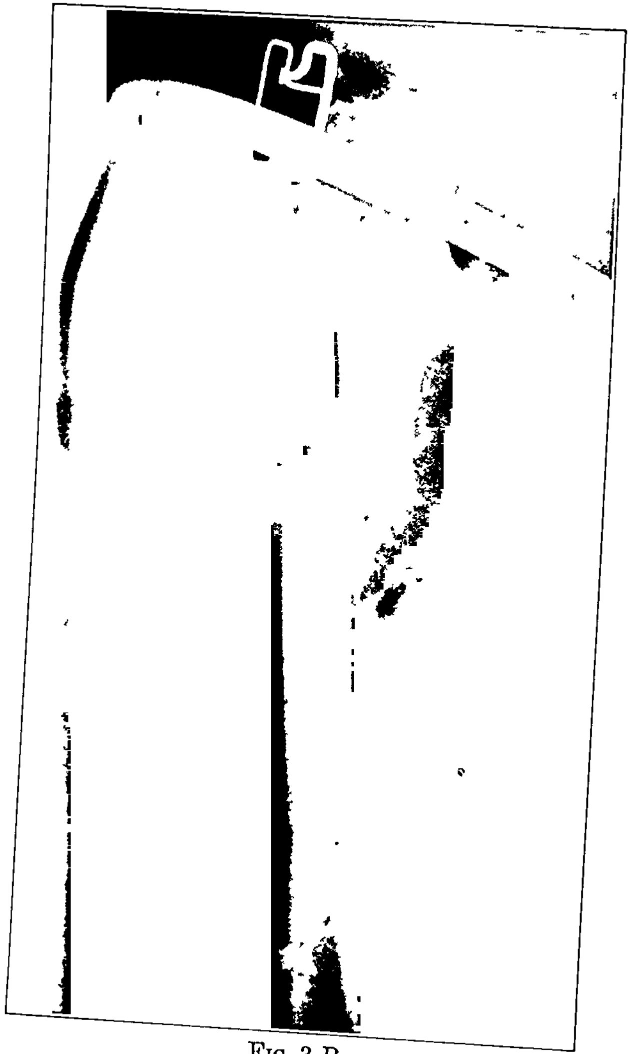

FIG. 3-B

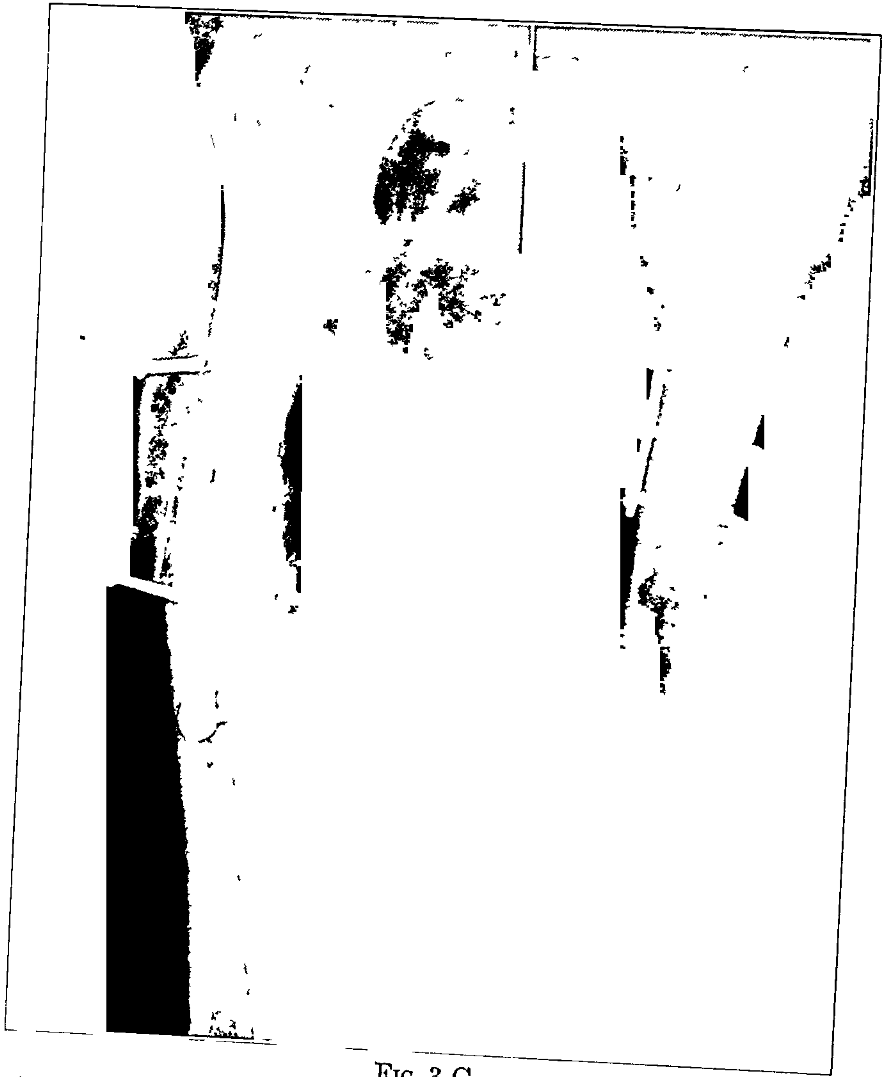

FIG. 3-C

Patient, aged twenty-one years, sustained a simple fracture of the right femur when struck by a motor vehicle. He was treated by skeletal traction in balanced suspension.

Fig. 3-A: Roentgenogram, showing apparently firm bony union, with good callus formation, five and one-half months following injury. At this time, patient was allowed to walk, in a well-fitting ischial weight-bearing brace.

Fig. 3-B: Roentgenogram, made seven days after Figure 3-A, shows refracture, which occurred while patient was getting into bed, in spite of adequate brace fixation.

Fig. 3-C: Sixteen weeks following combined iliac bone graft and plate fixation. Roentgenograms show disappearance of the fracture interval, firm incorporation of grafts into the host bone, and solid osseous union. At this stage, patient was ambulatory in an ischial weight-bearing brace.

might be used as an argument against leaving in the plate when a fracture has failed to unite, and against the use of plates at all with bone-grafts. The curetting out of all fibrous tissue at the fracture site, the packing of the interval with bone chips, and the use of the intramedullary and onlay grafts to bridge the fracture site invalidate such arguments.

METHOD OF TREATMENT

Preparation

Three or four days prior to surgery, if the patient is not already in skeletal traction, a Kirschner wire or a Steinmann pin is placed in the distal femur, using local anaesthesia. On the day of surgery the patient is brought to the operating room in a Thomas splint, with the weight operating over the end of the splint. He is operated upon with the weight still acting over the foot of the table, so that his fracture is protected at all times; immediately following surgery he is returned to the ward and again placed in balanced suspension.

The usual two-day sterile orthopaedic preparation is given to the involved extremity, as well as to the opposite iliac crest. Blood transfusions are given if necessary. It is important to have the patient in as good condition as possible, particularly in cases of frac-

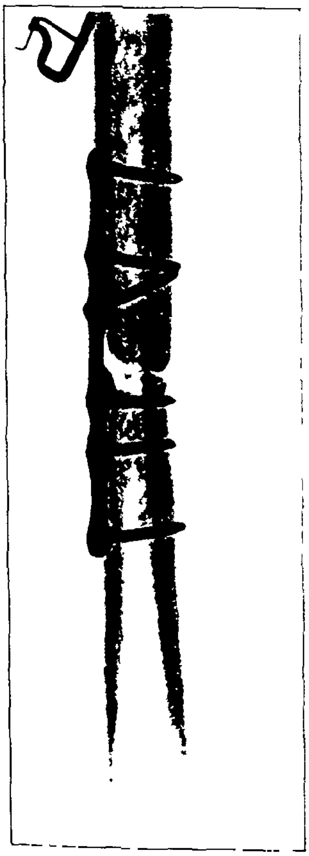

FIG. 4-A

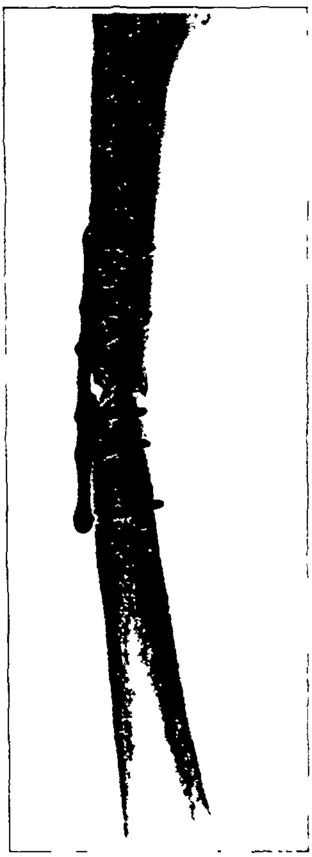

FIG. 4-B

FIG. 4-C

Patient, twenty-seven years old, received a simple, transverse fracture of the right femur, when struck by a vehicle. Treatment was by open reduction and plating, six weeks after injury.

Fig. 4-A: Roentgenogram shows fracture five months after injury. There is no evidence of callus, and a definite distraction interval is evident.

Fig. 4-B: Roentgenogram made two weeks after patient became ambulatory in a well-fitting ischial weight-bearing brace. The fracture had bowed, and the plate had loosened following breaking of its distal screw.

Fig. 4-C: Roentgenogram made sixteen weeks following combined iliac bone graft and plate fixation, the original plate having been re-applied more securely. The fracture site was no longer evident, union was firm, and the grafts had become well incorporated into the host bone. On this date, patient was ambulatory in an ischial weight-bearing brace.

tured femur where the patient has been confined to bed for from four to six months or longer. On the morning of surgery, an intravenous injection of normal saline solution is started as soon as the patient has been anaesthetized, and blood transfusion is substituted as soon as active bone work begins.

Surgical Procedure

The first operator, with one assistant, exposes the fracture site and proceeds with the plating; while a second operator, with one assistant, removes the grafts. A 15-centimeter curved incision is made from the anterosuperior iliac spine along the iliac crest, and the bone is exposed subperiosteally. The curves of the crest are trimmed with an osteotome, and the large graft is cut with a motor saw, beginning at the upper margin of the antero-inferior spine and proceeding posteriorly. Numerous smaller sliver grafts are then cut with the saw or an osteotome. After the grafts have been removed, the wound is packed to control bleeding, and the second team then assists the first.

In the case of a femur, a six-hole plate is applied laterally or, if a plate is already in place, it is checked for stability. With the double-bladed rotary saw a slot, 1.8 × 6.2 centimeters, is cut anteriorly across the fracture site, and this section of cortical bone is removed. The medullary cavity is opened at both ends, and all fibrous tissue is curetted from the fracture site. The slot is then filled with two or three sliver grafts of ilium, which can be made to fit quite firmly. The large graft is now placed over the inlay, after thor-

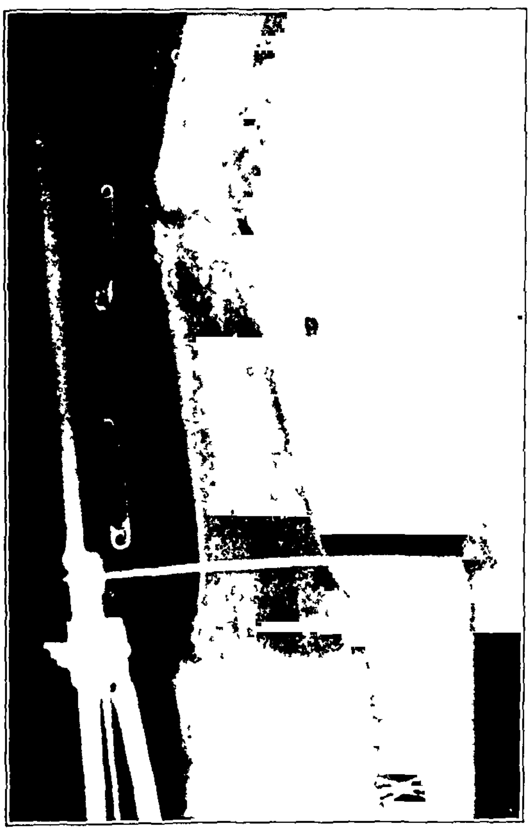

Fig. 5-A

Fig. 5-B

Patient, aged twenty-one years, sustained a compound, comminuted fracture of the right femur as a result of enemy shell fire.

Fig. 5-A: Appearance of fracture eight months after injury. There is no callus formation, and a complete non-union is present. The lateral bowing became exaggerated after the patient had been allowed up in an ischial weight-bearing brace for two weeks. The numerous metallic bodies in the region of the fracture are shell fragments.

Fig. 5-B: Roentgenograms, made immediately postoperatively, show very strikingly the mechanical principles of the combined operation. The massive illiac bone graft, held with two screws and washers, has been placed across the fracture site, overlying the trough with intramedullary grafts, at right angles to the six-screw plate. This patient was ambulatory, sixteen weeks following operation, in an ischial weight-bearing brace, osseous union being firm, and the graft well incorporated into the host bone.

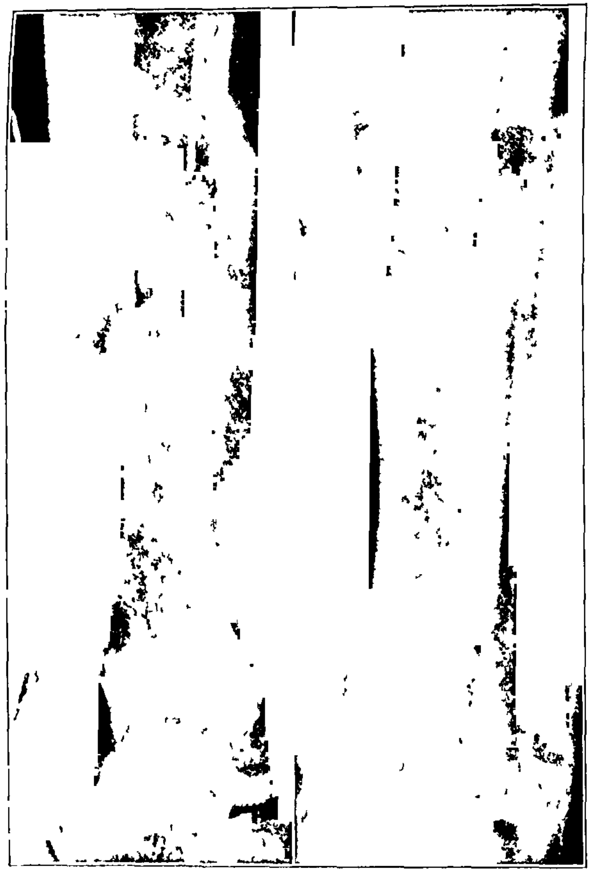

FIG 6-A

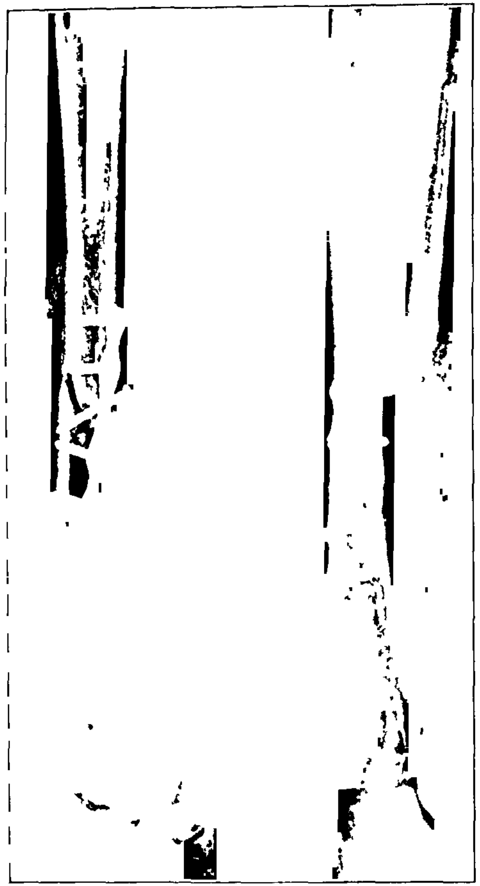

FIG. 6-B

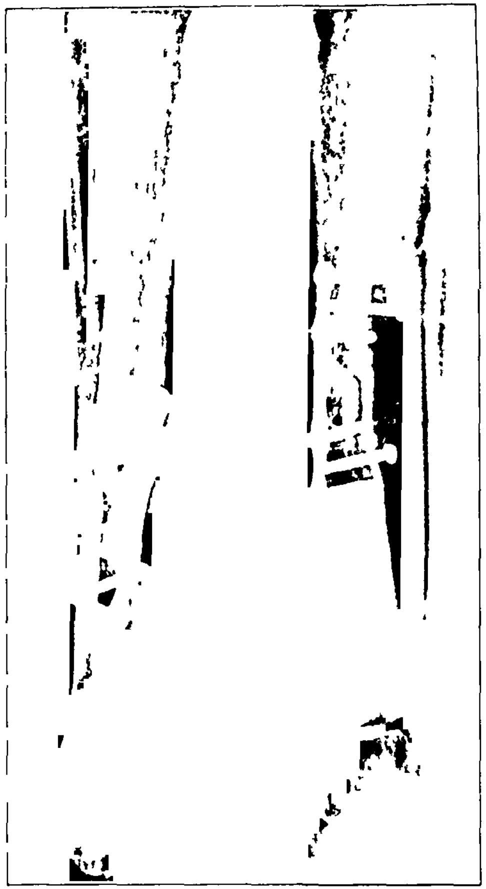

FIG 6-C

Patient, aged twenty years, sustained a simple transverse fracture of the left tibia and fibula in a plane crash

Fig 6-A Position of fragments prior to open reduction.

Fig. 6-B: Fracture was immobilized with four-screw plate and fixation screw. Five months after injury there was no callus present, and a distinct interval was evident at the tibial fracture site. The fibula was well united.

Fig. 6-C At operation, the original plate was not disturbed, but the transfixion screw was removed. Roentgenograms, six weeks following the operation, show the graft viable and already well incorporated Patient was allowed to bear weight in a walking cast at the sixth week after operation, and in a tibial caliper brace at the fourteenth week, at which time complete bony union was present.

ough drilling of its contact surface. Because of its greater length, this onlay graft extends over cortical bone beyond the limits of the inlay. The graft is fixed with two screws, which usually pass between the first and second and the fifth and sixth screws in the plate. The heads of these screws are often widened by addition of a flat washer, to prevent their cutting through the soft iliac bone. The screws engage both cortices of the host bone after passing through the graft. Just before placement of the grafts, the fracture ends are thoroughly drilled as an additional aid to union. After the grafts have been placed, the second team closes the iliac incision, while the first closes the extremity incision (Fig. 1).

Postoperative Care

All of the femora have been treated with skeletal traction in a Thomas splint as the only fixation. Twelve pounds of weight are used on a Steinmann pin or Kirschner wire through the distal femur. In ten patients operated upon, this has been adequate, and in no patient has position been lost. The patients are quite comfortable, and early knee motion is instituted. This feature of the procedure is made possible by the addition of the plate to the bone graft. The skeletal traction has been changed to skin traction after ten or twelve weeks in all cases. It may be found possible to make this change earlier. The first five patients in this series have become ambulatory in ischial weight-bearing braces sixteen weeks after the operation.

RESULTS

The indications are that very rapid union and incorporation of the graft from the ilium occur, as will be seen in the following analysis. Sixteen operations have been performed by this technique.

Ten were for fractures of the femur, three of which were compound. Surgery was not attempted in the compound fractures until six months after cessation of drainage. The actual time before operation in these ten cases ranged from three to nine and one-half months from the date of injury. In four of the simple fractures, platings had been done from one to six weeks following injury. At the time of operation, all patients had complete non-union or delayed union, without evidence of callus. Only one patient was operated upon as early as three months after injury; this was done because of marked displacement of bone ends, with interposition of soft tissue. Results in these ten cases of fracture of the femur are as follows: Five are solidly united and the patients became ambulatory, in ischial weight-bearing calipers, sixteen weeks following operation. This includes one patient who, in addition, had a non-union of the opposite tibia, which was also grafted with ilium, and the patient was made ambulatory in a cast and brace. The other five patients were operated upon less than sixteen weeks before the date of this report, but each is showing the same rapid incorporation of the grafts. No complications have occurred (Figs. 5-B and 6-C).

Four patients had fractures of both bones of the forearm, two compound and two simple, three of which were plated two weeks after injury; in all four there was non-union. Bone-grafting was done from six to nine and one-half months after injury, in the same manner as that described for femora. There have been no complications. All four patients have obtained solid union in twelve weeks or less.

One simple fracture and one compound fracture of the tibia complete the series. The simple fracture had been plated four days after injury, and an additional transfixion screw had been inserted. In this case an iliac graft was used five and one-half months after injury. The patient was ambulatory, and the bone was firmly united fourteen weeks after the operation (Fig. 6-C). The compound fracture presented a considerable defect, due to loss of bone, and fixation was obtained by means of a six-screw plate and a flange bone graft. The patient has been operated upon too recently to evaluate the results.

In all cases there was healing without infection, and there were no complications except one malarial relapse three days after operation.

RESTORATION OF MUSCLE POWER BY HEAVY-RESISTANCE EXERCISES

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Exercise is essential in restoring function to muscles, weakened and atrophied as a result of injury and disease. Therapeutically, exercises may be classified according to the quality developed in the exercised muscle,—namely, power, endurance, speed, and coordination. Failure to discriminate between these classes of exercises leads to the employment of the wrong type of exercise to develop the quality needed in the muscle; inevitably the result is poor. Commonly the attempt is made to restore power by exercises to build endurance; this is a mistake.

This paper deals with the redevelopment of muscle power, chiefly in the quadriceps, although some consideration will be given to other muscles.

PRELIMINARY CONSIDERATIONS

Most injuries of the thigh and knee result in atrophy of the quadriceps of varying degree. When the local injury has healed, redevelopment of quadriceps power is the most important factor in restoring normal function to the extremity. The method here presented for developing muscle power by exercise is founded on the principle of heavy-resistance and low-repetition exercises, whereas the generally accepted principle is low-resistance and high-repetition exercises—such as stationary-bicycle riding, lifting light sandbags or other weights through ropes and pulleys, stairclimbing, *et cetera*—which develop endurance rather than power. The fatigue that results from the latter is not due so much to overcoming resistance, as to the sheer number of repetitions; therefore, such exercise does not develop power. If low resistance is used for a low number of repetitions, no significant increase in either power or endurance results, and the only value lies in increasing slightly the joint motion. On the other hand, in our method we employ heavy resistance that calls forth all the potential strength of the muscle. Since the rate and extent of muscle hypertrophy is usually proportional to the resistance the muscle must overcome, strength returns faster than in the low-resistance exercises. We believe this to be true, because we have seen many patients fail to obtain any appreciable quadriceps hypertrophy during several months of low-resistance exercises; whereas, with the heavy-resistance exercises, we have uniformly recorded rapid hypertrophy (in several instances two to two and a half inches of hypertrophy of the thigh muscles within six to eight weeks). Power is developed in the affected thigh until it equals that in the normal. When the strength of the limbs is approximately equal, then endurance exercises may be begun. Rather than attempt to develop endurance in an atrophied, weakened muscle, it seems more logical to restore muscle strength to normal, and then build endurance by means of low-resistance, high-repetition exercises.

The quadriceps exercise described is particularly valuable, for it develops maximum power without weight-bearing. Since it is a non-weight-bearing exercise, it is especially useful in redeveloping the musculature following meniscectomy, and in unstable knees. In these two conditions, particularly when there is quadriceps atrophy, weight-bearing exercises (such as bicycling, stairclimbing, *et cetera*) frequently cause swelling and fluid. Except in rare instances, we have seen neither swelling nor fluid on maximum exertion with these non-weight-bearing exercises. In most of our cases, these symptoms have actually completely subsided on exercise. After these patients have succeeded in restoring

normal power to their injured limbs, they are able to do the light weight-bearing exercises mentioned without either symptom developing.

PROGRAM OF EXERCISES

In this program of heavy-resistance exercises, the patient exerts his maximum power only once a week. The maximum quadriceps power for clinical purposes is taken to be the maximum poundage that can be raised to the point of complete extension of the leg, for one repetition. It is recorded in pounds. Once each week the patient exerts the maximum effort of which he is capable for one repetition. On the other days, no weight heavier than that which is maximum for ten repetitions is used. This program of periodic maximum muscular exertion is used even on the most atrophied muscles. Contrary to the popular belief that after injury the quadriceps should never be exercised to its limits, we have never produced chronic muscle sprains or failed to achieve return of muscle power.[2] On the basis of clinical observations in 300 cases in which this program of exercises was used, we firmly believe that even extremely atrophied muscles should exert their maximum effort at regular intervals.

Description of Exercise

The patient is seated on the table with his knees flexed at an angle of 90 degrees, and the boot is strapped on the foot. A folded blanket or pad is placed under the knees. The patient is now in the starting position, as illustrated in Figure 1. The leg is extended as completely as the disability will permit. The leg should be extended and lowered at the same rate. The movements are done smoothly, rhythmically, and without haste, but not so slowly that the mere holding of the weights will tire the patient. Quick or sudden motions while exercising are to be avoided. A momentary pause at the end of each repetition is advocated.

The importance of complete extension with each repetition cannot be overemphasized. The vastus medialis functions chiefly by carrying the leg through the last 15 degrees of extension. The disproportionately rapid atrophy of this muscle following injuries of the lower extremity and prolonged immobilization with resultant inability to completely extend the leg is a familiar clinical picture. Restoration of strength to the vastus medialis is a major problem to orthopaedists and physical therapists. If there is sufficient strength present to carry the leg either partially or completely through the last 15 degrees, the problem is not too great. However, if there is complete inability to extend through the last 15 degrees, the problem calls for more strenuous measures. In these cases it would be im-

Fig. 1
Quadriceps exercise, using one boot.

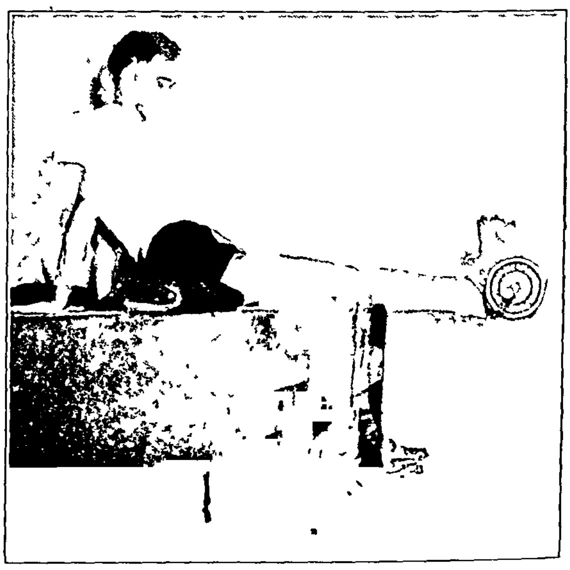

Fig. 2
Quadriceps exercise, using two boots.

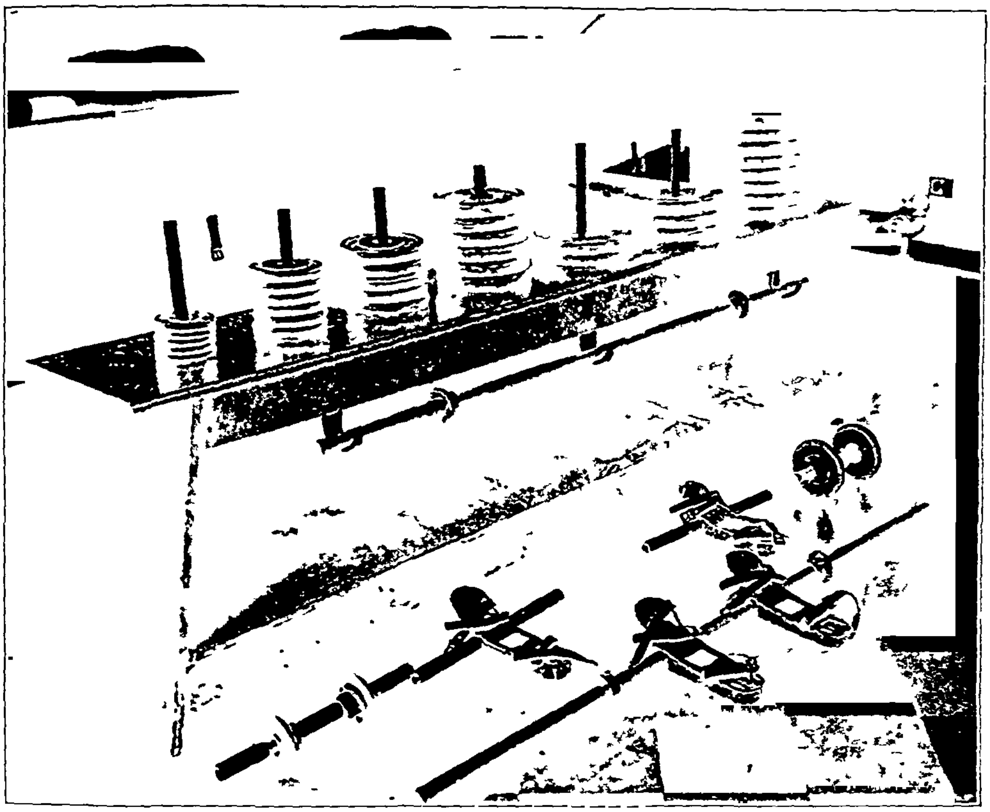

Fig 3

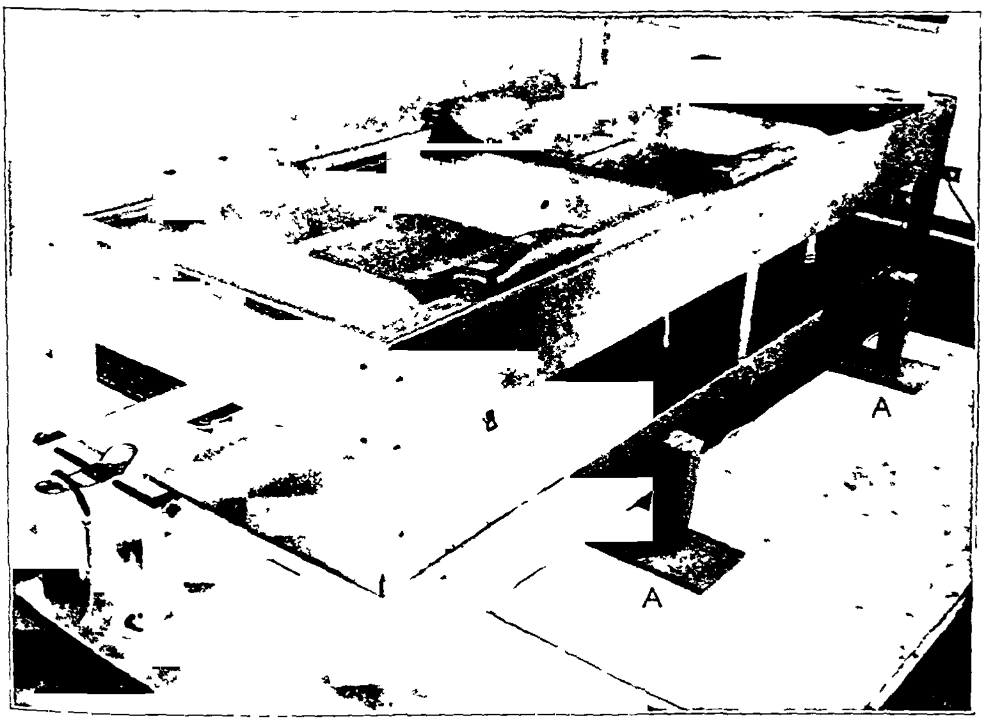

Fig 4

Quadriceps-exercise table The weight stands (A) are to rest the weight upon between sets of exercises

possible to redevelop vastus medialis power, if the only function of this muscle were extension in the terminal 15 degrees; but the muscle also functions through a much larger range of motion when the leg must overcome a very heavy load. This fact makes it possible to exercise the vastus medialis actively in the available range of extension, thereby building power that will eventually make it possible to completely extend the knee. Sufficient vastus medialis power to produce complete extension can be built by using heavy resistance through the available range of motion. On each repetition, when the patient has reached his maximum extension, he should be taught to expend an extra effort at this point to attain even more extension.

At the beginning of the exercise and until the limbs are approximately equal in strength, only the affected extremity is exercised. Only one boot and a short bar are used, as shown in Figure 1. When the limbs are approximately equal in strength, then they are exercised simultaneously, using two boots attached to a long bar as shown in Figure 2. It is advisable for the patient to use two boots for a while to increase strength in the unaffected extremity, since this extremity becomes considerably weakened from disuse. When both boots are used, the principles of exercise, poundage increase, repetitions, *et cetera* remain the same as when one boot is used.

Apparatus

Resistance is offered in the form of iron plates, graded from one and a quarter to twenty-five pounds each. These plates are attached to an iron boot by means of a short iron pipe which fits into the boot. This boot is made especially for leg exercises. The iron boots, plates, and bars are shown in Figure 3.

The exercises are performed on a table which should be thirty-six inches high and at least fifty inches wide. The legs and top of the table should be of heavy material and reinforced, since it will be subjected to considerable strain. The edge should be raised two to three inches so that, when the leg is completely extended, the entire limb will be parallel to the floor. The quadriceps-exercise table is shown in Figure 4.

Repetitions and Weight

Fifteen is the maximum number of repetitions ever performed in series, regardless of the amount of weight lifted. Ten or twelve is the number generally performed. The total number of repetitions for an average exercise period varies from seventy to 100,—that is, seven to ten series of exercises with ten repetitions in each.

The Ten-Repetition Maximum (10 R.M.)

The amount of weight lifted by the patient at any single extension during his first week of exercise is determined at the time of his initial workout, as follows: Starting with the weight of the boot (five pounds), and increasing by small amounts (one and a quarter to five pounds), the patient lifts each weight ten repetitions. That weight which requires maximum exertion to perform ten repetitions is thus determined. For the remainder of the week, no weight heavier than this ten-repetition maximum (10 R.M.) is used. Once each week the patient makes an attempt to increase this 10 R.M., and, when this amount is determined, no heavier weight is used during the ensuing week. For example, a patient in his first workout finds that the heaviest weight with which he can perform ten repetitions is twenty pounds. Thus, during his first week, he uses nothing heavier than twenty pounds. At the end of the first week, the 10 R.M. is again determined, and found to have increased to thirty pounds. Then thirty is the maximum poundage used during his second week of exercise, *et cetera*.

Since seventy to 100 repetitions must be performed in each workout, and each poundage is done ten repetitions, the workout must be begun with a weight considerably less than the 10 R.M., so that when the 10 R.M. has been reached, seventy to 100 repetitions will have been performed. The example given can be continued to illustrate this. The

10 R.M. for the first week was twenty pounds. By starting with two and a half pounds, plus the weight of the boot, and increasing one and a half pounds after each series of ten repetitions, eighty repetitions will have been performed when twenty pounds is reached.

The One-Repetition Maximum (1 R.M.)

As previously stated, once a week the patient exerts his maximum quadriceps power (maximum weight that can be lifted with one repetition, the knee going into complete extension). This one-repetition maximum (1 R.M.) is determined on the same day as the 10 R.M., in the following manner: When the 10 R.M. has been determined, the increases in weight are continued. With each increase beyond the 10 R.M., fewer repetitions can be done until finally that weight which can be extended only for one repetition with maximum exertion is reached. This is recorded weekly as the index of quadriceps power.

As strength returns to the muscle, the weight increases may be five to ten pounds, rather than one and a quarter to two and a half, thus keeping the total number of repetitions for a workout within the range of seventy to 100.

Of course there are many patients who, because of severe quadriceps weakness, have an initial 10 R.M. of less than five pounds. In these cases, the procedure is altered, and we use two or three series of ten repetitions each without any weight, add one and a quarter pounds, and give two or three series more. Then, by increases of one and a quarter pounds, his 10 R.M. is finally determined. (When the patient is unable to begin the exercises with the weight of the boot, five pounds, the smaller weights are attached to the foot by means of a leather strap.)

In those cases where there is incomplete extension due to muscle weakness, the program is further altered. After the patient has performed ten repetitions with the maximum poundage which can be extended to the same degree as when no resistance is being applied, he then continues to increase the poundage at the sacrifice of extension. The poundage increase is continued until the knee can be extended only a few degrees. Exercising in this way through the available range of motion is necessary where muscles are extremely atrophied, in order to build enough power eventually to effect complete extension. This is especially true when the vastus medialis is weak.

Frequency and Length of Workout Periods

The patient exercises once a day, five days a week, the workout period usually lasting one-half hour. He is encouraged to rest his leg as much as possible during the two days he does not report for the exercises. Since the exercise periods are short and come only once daily, the patient does not tire of the program, as is often the case when an exercise must be practised hourly or several times a day.

Data Recorded

The following measurements are recorded weekly:

1. Range of motion,
    a. Extension,
    b. Flexion,
2. Thigh circumference,
3. Power,
    a. 1 R.M. (one-repetition maximum),
    b. 10 R.M. (ten-repetition maximum).

The weekly determination of the 1 R.M. and the 10 R.M. is made on the same day. For convenience, we designate Friday as the day on which the quadriceps power is determined. There should be a two-day rest following this day of maximum exertion, and this arrangement makes it unnecessary for the patient to exercise over the week-end.

The thigh is measured once a week, at a constant level. Silver nitrate is used to mark

the level, to make sure that every measurement is taken in the same place. Daily observations are made for development of fluid, swelling, pain, *et cetera.*

The maximum quadriceps power is determined, and thigh measurements of the unaffected extremity are taken, when the exercise program is initiated. Maximum results have been obtained when both extremities are equal in power, circumference, and range of motion.

OBSERVATIONS

Symptoms Developing as a Result of Exercises

The only symptom that developed as a result of exercise was soreness of the quadriceps muscle. This soreness invariably disappeared within a week. In no instance has swelling or fluid appeared in the knee joint secondary to the strenuous exercises.

Development of Power in the Existing Range of Motion

Too often the main stress is placed on increasing motion in the atrophied, weakened limb with a limited range of motion, and very little or no thought is given to developing power. Nicoll states that "range without power is worse than useless, for in its extreme form we have a flail joint".[2] The return of power should accompany return of motion. It is more desirable to have normal power in the existing range of motion than to sacrifice development of power for a wider range of motion. The exercises we advocate are planned so that return of power accompanies return of motion. We believe that range of motion increases more rapidly with increasing muscle power, except when a mechanical factor prevents return of motion.

Focal Exercises versus Group Exercises

We are convinced from our observation of patients indulging in group exercises and games, as performed in reconditioning programs, that group exercises for focal muscle redevelopment are unsatisfactory because:

1. The mental factor governing muscle exertion is such an important one in attaining maximum results that the patient must concentrate completely, and actually watch (whenever possible) the muscle being exercised throughout each repetition. Group participation offers too many factors to divert the patient's attention.
2. If a patient is unable to perform the movements as well as others in the group, he may feel his inadequacy to such an extent that he will attempt to cover up his weakness by adopting compensatory trick movements, thus accomplishing the feat with other muscles than the one which he is attempting to redevelop.
3. For the patient who must be prodded along, it is much easier for him to conceal his half-hearted efforts in group exercises.
4. Since there are individual variations in strength, symptoms, and types of injuries, it seems illogical to give exercises to groups of patients with the same repetitions, motions, resistance, and tempo.

Endurance versus Power

We feel that in the past one of the shortcomings of the conventional type of physical therapy for redeveloping musculature has been a failure to discriminate between endurance-building and power-building exercises. By "power-building" exercises we mean exercises in which heavy resistance is used for a low number of repetitions. "Endurance-building" exercises are those in which low resistance is used for a large number of repetitions. These are two entirely different types, each one producing its own results, and each being wholly incapable of producing the results obtained by the other. We feel that most current attempts to redevelop musculature are based on exercises which are, in the final analysis, endurance-building and not power-building in nature. We feel it is wrong, for example, to put a patient with an extremity weakened by injury on such endurance-building exercises

as stairclimbing, walking, bicycling, and similar low-resistance exercises, until the extremities are approximately equal in strength.

A muscle exercised solely on power-building exercises will not have the quality of endurance, whereas a muscle subjected exclusively to endurance-building exercises will not have the quality of power. However, a powerful muscle can be given endurance-building exercises, and attain the quality of endurance; likewise a muscle with great endurance can attain power through the power-building exercises. How illogical it would be for a track man to train for long-distance running events solely by doing knee bends with heavy weights on his shoulder, or a professional weight-lifter to train for heavy lifts solely by running several miles a day!

It seems more logical to restore the weakened extremities to normal strength by power-building exercises and then to exercise for endurance. Endurance is a quality of normal muscle, and therefore should not be sought after until the muscle has returned to normal. We believe it unlikely that endurance can be attained in a markedly atrophied muscle, for we have seen many patients who had been on low-resistance, high-repetition exercises for months, and still complained of rapid tiring of the muscle.

Physiological Aspects of the Heavy-Resistance Exercises

It is not the purpose of this paper to discuss neuromuscular or muscle physiology. We are presenting only the clinical observations made on 300 cases in which these exercises have been employed. The splendid response in muscle hypertrophy and power, together with symptomatic relief, seems to vindicate any possible violation of physiological principles. Competent physiologists who have observed these patients and our method of exercise feel fairly certain that the fatigue produced is at the neuromuscular junction, and not of the muscle fiber itself.

The question arises as to whether it is advisable to induce maximum loads on weakened and atrophied muscle fibers. We firmly believe, on the basis of our clinical observations, that even atrophied musculature must be submitted intermittently to maximum loads, in order to obtain maximum hypertrophy. We have treated several cases of fractured femur which had been immobilized from six to fourteen months. The thigh muscles were very hard on palpation, suggesting fibrosis, and lacked power. These responded in four to five weeks, showing an increase in thigh circumference of one to two inches and a remarkable increase in power. They were under maximum loads at regular intervals from the very beginning. It was interesting to observe how quickly these muscles softened and assumed the consistency of normal muscle. This observation throws an interesting light on hypertrophy and return of power in fibrotic muscle.

We believe that, in order to produce in muscle maximum hypertrophy, the heaviest load should be imposed upon the muscle as it approaches complete contraction, and not when the muscle is stretched. It is an accepted physiological principle that the greater the initial stretch or tension on a muscle (length), the greater the contractile power of the muscle. Therefore, when the maximum load is imposed on a stretched muscle, its fibers have the initial advantage rendered by the stretched state, and fewer fibers can overcome the resistance than if the muscle were not stretched. When the muscle fiber is contracted, it does not have this advantage. In order to overcome the resistance, a greater number of fibers are called upon; more fibers are exercised and thus stimulated to hypertrophy. Also, by increasing the load as the muscle reaches the contracted state, a higher degree of coordination of the contracting muscle fibers is obtained, increasing the contractile power of the muscle as a whole. Most of the power-building exercises here described are so arranged that resistance increases as the muscle contracts.

The use of a pulley system for quadriceps redevelopment has the disadvantage that the maximum resistance comes when the muscle is stretched. The pulley system as contrasted with our method is demonstrated in Figures 5-A, 5-B, 5-C, and 5-D. We do not

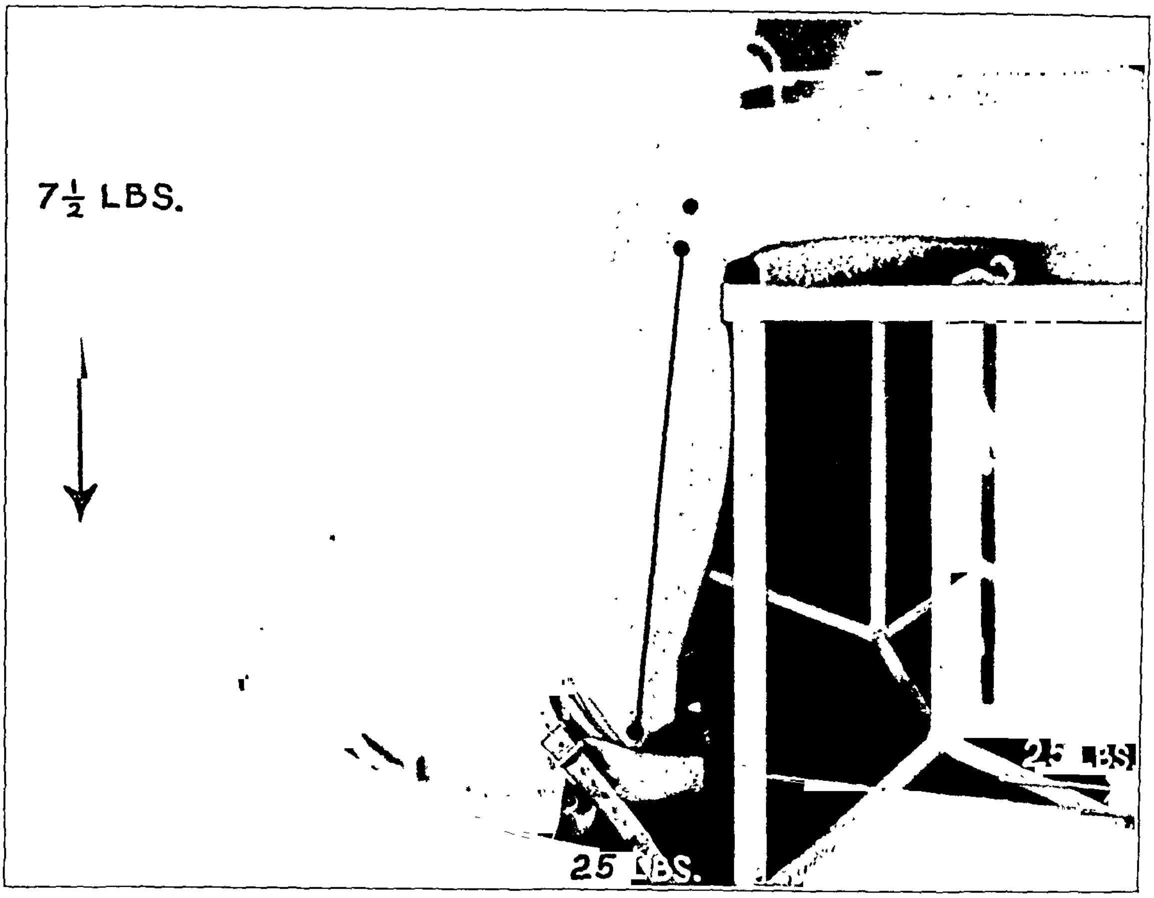

Fig. 5-A

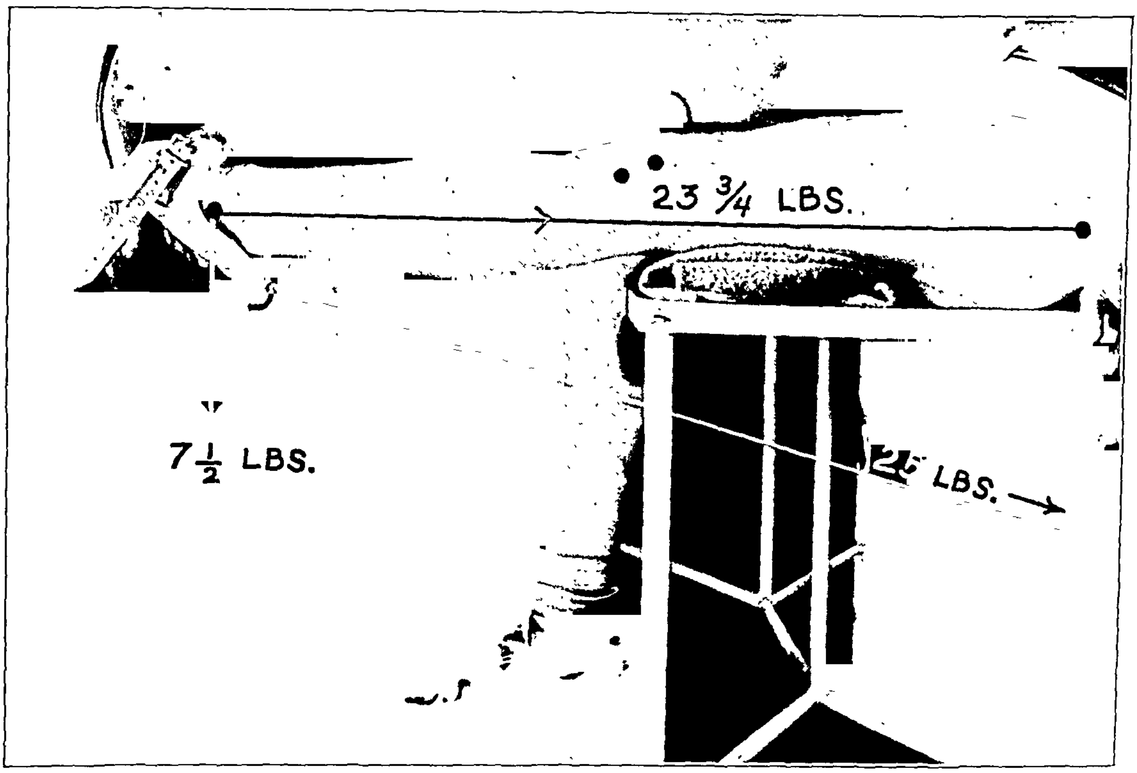

Fig. 5-B

The pulley system with knee flexed in starting position is shown in Fig. 5-A. There is 25 pounds of resistance on the pulley system, applied to the leg through the rope shown attached to the foot. The long axis of the leg in the starting position is perpendicular to the rope. At this point the resistance consists of the full 25 pounds. However, as the leg extends, the rope comes to lie at a more acute angle to the shaft of the leg, and the amount of resistance to be overcome decreases; so that, when the leg is fully extended (Fig. 5-B), the resistance to be overcome has decreased to only 7½ pounds. In full extension, 23¾ pounds of the initial 25 pounds of resistance are lost as a compression force in the direction indicated by the arrow, leaving as a resultant of forces, only 7½ pounds of resistance to be (*Continued on page 653*)

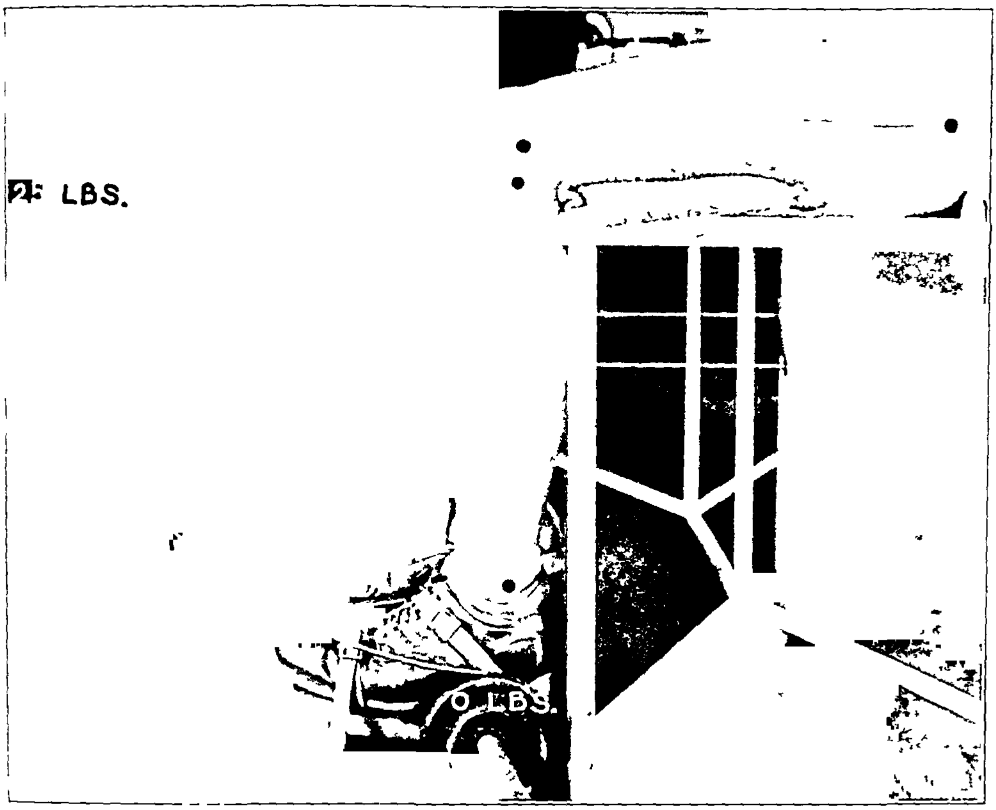

Fig 5-C

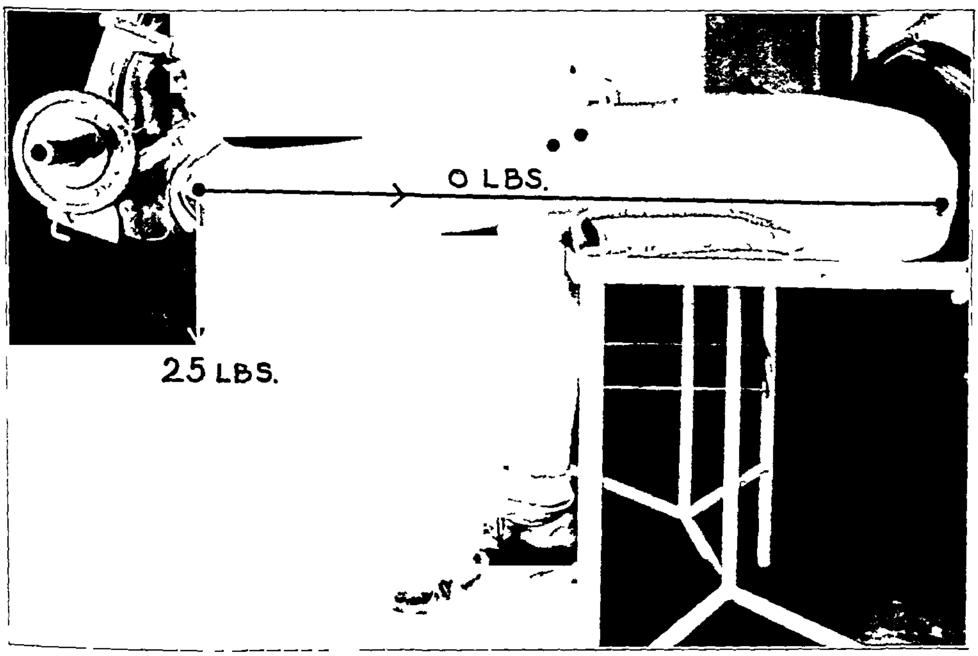

Fig 5-D

(*Continued*) overcome by the quadriceps Thus we see that the pulley system is one of decreasing resistance as the leg goes into extension Therefore, when that part of extension controlled chiefly by the vastus medialis is reached, the resistance has greatly decreased; thus this muscle is neglected in the strenuous phase of the exercise

When the resistance is added directly to the foot, the reverse of the above situation exists In the starting position (Fig 5-C), the resistance is practically nil, but as the leg extends, the resistance rapidly increases and is maximum (25 pounds) when the leg is completely extended (Fig 5-D). There is no compression force as is present in the pulley system The vastus medialis receives the chief benefit from this exercise

mean to imply that pulleys are of no value in giving heavy-resistance exercises; on the contrary, they often afford the only means of exercising a certain muscle group. However for redevelopment of such an important group as the quadriceps, it is felt that the pulley system is inadequate.

Maintenance of Hypertrophy and Power

The progress of several patients has been followed for ten months after terminating this program of intensive exercise. Measurement at this time revealed no appreciable loss of muscle size or power, and there was no return of the symptoms previously noted,—such as giving way of the knee or weakness of the extremity. The patient can best maintain the power gained by exercising once or twice a week for fifteen to thirty minutes at a time. It is comparatively easy to maintain the power, once it has been attained.

Types of Cases in which Exercises are Used

1. Unstable knees resulting from tears of the cruciate and collateral ligaments.
2. Knees following removal of the menisci—lateral, medial, or both. The program has been used vigorously following total synovectomy of the knee, with good results.
3. Fractured femora.
4. Fractures of the patella.
5. Recurrent dislocation of the patella.
6. Fractures of tibia and fibula where prolonged immobilization has brought about quadriceps atrophy, as well as atrophy in other muscles of the extremity, and limited motion in the knee joint.
7. Knees following chondrectomy for chondromalacia of the patella.
8. Muscle weakness and limitation of joint motion, due to severe soft-tissue wounds and scarring.
9. Removal of foreign bodies from the knee joint.
10. Knees after patellectomy.

The best results have been obtained in cases of unstable knees, meniscectomies, and fractured femora. We believe the exercises are contra-indicated in cases of chondromalacia, in which the disease is accompanied by pain, swelling, and fluid, and where open operation has not been performed.

DISCUSSION OF CASES

Knee Instabilities

The most dramatic results have been obtained in cases of instability of the knee, of which twelve have been subjected to these exercises. In each the ligamentous injuries were old, and had not responded satisfactorily to previous treatment. Three are presented in detail, and serve to illustrate the progress made in most cases. The instabilities varied in nature: nine with injuries to the anterior cruciate and tibial collateral ligaments; one with injury to the tibial collateral ligament, with marked relaxation; one with injury of the anterior and posterior cruciate and tibial collateral ligaments; and one with injury of the anterior and posterior cruciate and fibular collateral ligaments.

The type of injury did not seem to influence the results, inasmuch as rapid gains and alleviation of symptoms occurred in the extremely loose joints as in the less unstable joints. Four of the twelve were wearing Jones knee cages when they began the exercises. Two patients discarded the braces after fourteen days, one after twenty-one days, and another after twenty-three days. In other words, the average time from beginning the exercises to the time when the patients had enough quadriceps power to safely begin ambulation without the brace was eighteen days. Eight of the twelve were able, after from four to six weeks, to run and play ball, without their braces and without "buckling" of the knee. Nine of the twelve had varying degrees of fluid and swelling when exercises were started; in eight of the nine these symptoms disappeared in one to three weeks. In one patient a

slight amount of swelling persisted. Ten of the patients had pain on exercising and weight-bearing initially; seven lost the pain; three did not.

In all cases, after maximum benefit had been derived from the exercises, the instability persisted unchanged when the quadriceps muscle was relaxed. However, when the quadriceps muscle was contracted, it was impossible to demonstrate any looseness about the joint. A powerful quadriceps renders the knee stable only when it is contracted; but,

FIG. 6

Roentgenographic studies for tear of the tibial collateral ligament, showing positive abduction spread.

FIG. 7

Positive drawer sign for tear of anterior cruciate ligament.

when contracted, offers sufficient stability for ordinary activities and, as demonstrated b some of our cases, even for rather strenuous sports. It is the purpose of the exercises t build the quadriceps muscle to become powerful enough to maintain the stability of th knee, without the full help of the ligaments. Normal quadriceps power is not sufficient fo this, so greater-than-normal power must be built in the involved extremity. This explain why we use such extremely heavy resistance in cases of knee instability. In fractured femora meniscectomy cases, *et cetera,* where the knee is stable, the purpose is to restore norma power to the injured leg; therefore, redevelopment is not pushed to such an extreme degree

In none of the twelve cases were there any ill effects from the strenuous program o exercise.

The splendid response of these patients to exercise alone suggests that in certain type of old ligamentous injuries, surgery may not offer more.

An officer sustained an injury of the tibial collateral ligament, following which he was immobilize in a cylindrical plaster cast for seven weeks. After removal of the cast, he received physical therapy fo seven weeks before the heavy-resistance exercises were begun. At the time the exercises were begun, h had a marked limp, walked with a cane, complained of pain about the knee, and the knee was slightl swollen. In twenty-one days his knee was completely asymptomatic; he had equal power in both quad riceps muscles; and had gained three-quarters of an inch in circumference of the thigh. His maximun quadriceps power increased from ten to eighty pounds. This patient returned to limited duty with th infantry, with automatic revision to full duty.

A soldier sustained a complete dislocation of the knee when he fell from a four-foot platform. Tw weeks after injury, a meniscectomy was performed, and the patient returned to duty, but was unable t continue because of pain on weight-bearing. Five months after the initial injury, another arthrotom was done, a partial tear of the anterior cruciate ligament being sutured and a fascial flap placed at th site of the tibial collateral ligament. Instability persisted, and, eleven months after the initial injury, third operation was done, at which time a fascial reconstruction of the tibial collateral and anterio cruciate ligaments was undertaken. Again the instability persisted, and the patient was fitted with Jones knee cage. Three and one-half months after the last operation, the patient undertook the heavy resistance exercises. At this time there was atrophy of the thigh of two and one-half inches, flexion o 58 degrees, maximum power of two and one-half pounds, and moderate swelling of the knee joint. I fifty-two days of exercise, the patient made the following gains: a power increase of sixty-two and quarter pounds in the quadriceps, an increase of two inches in circumference, and a gain of 42 degree in range of motion. By the end of the third week of exercise, he had discarded the knee cage. Pain an swelling rapidly disappeared. The patient was discharged from the Army because of his knee injury took a job as a truck driver, and his knee has remained asymptomatic.

Another soldier sustained injury to the tibial collateral and anterior cruciate ligaments while skiing Figure 6 shows the increase in the medial joint space due to injury of the tibial collateral ligament Figure 7 shows the positive drawer sign for tear of the anterior cruciate ligament. Following the injury the patient had pain, thickening, and fluid in the knee. For four and one-half months he had conven tional physical therapy, without improvement. After this period, a Jones knee cage was worn. Even wit the brace, and while walking on level surfaces, he frequently would fall, because of the instability an muscle weakness. After using the knee cage for seven weeks, he undertook the program of heavy resistance exercises. Two weeks later, his quadriceps power had increased to such an extent that he fel secure enough to give up his knee cage. The symptoms of pain, fluid, and thickening had completel subsided by this time. After one month of the exercises, the patient had gained one and one-half inche in circumference of the quadriceps, with increased power in that muscle of from twenty to eighty pounds and he could sprint over uneven terrain at full speed without difficulty.

Meniscectomy Cases

These patients were given quadriceps-setting exercises for several days preoperatively, and the exercises were resumed as soon after operation as possible, usually in twenty-fou to forty-eight hours. Quadriceps setting was continued until the synovitis had largely subsided, and the discomfort from weight-bearing was minimal; this required three to four weeks. They were then started on the heavy-resistance exercises, and, with maximum exertion on these exercises, the synovitis continued to disappear.

Twenty patients have exercised postoperatively by the heavy-resistance method. Seventeen of the twenty had definite synovitis of the knee joint at the time exercise was

begun, and in only two of them did the degree of synovitis fail to decrease. In no instance was there exacerbation of synovitis due to the strenuous exercise. No patient was allowed to participate in weight-bearing exercises until the quadriceps power had been restored in the limb operated upon.

The average time required to restore normal power to the affected extremity was nineteen days. Only two of the twenty patients failed to regain normal quadriceps power, and these two developed their quadriceps power to within 80 per cent. of normal. Restoration of normal power and thigh circumference can be expected to occur at a much more rapid rate following meniscectomy than in cases of fractured femur, fractured patella, ligamentous injuries, *et cetera*, where the period of immobilization is usually more prolonged. It must be stressed that, following meniscectomy, the quadriceps-setting exercises given postoperatively are as important as the heavy-resistance exercises in obtaining good end results.

Restoration of a normal range of motion offered no problem in any of the twenty cases. All patients had normal knee-joint motion on completion of the exercise program. A few had difficulty in obtaining the last 15 or 20 degrees of flexion. These, however, responded rapidly to treatment on the leg-exercising apparatus (Fig. 8).

WEIGHT-BEARING AND NON-WEIGHT-BEARING QUADRICEPS EXERCISES

At this point it is appropriate to discuss briefly these two types of exercises. As far as increasing muscle power is concerned, both types have equal possibilities. They differ, however, in the symptoms they produce in knee joints controlled by weak, atrophied muscles.

We believe that the development of pain, thickening, and fluid on weight-bearing exercises in many of the cases of meniscectomy and unstable knees is due largely to the increased laxity in the joint, resulting from quadriceps weakness and atrophy. We have seen many of these patients with marked synovitis in the knee joint, in whom complete alleviation of knee symptoms occurred, when quadriceps power was restored to normal by non-weight-bearing, heavy-resistance exercises. The instability results in repeated strains which produce a traumatic synovitis[1] with fluid, thickening, and pain.

Of the twenty patients who had meniscectomies, seventeen had fluid, swelling, or both, of varying degree, when they began these exercises three or four weeks after the operation. On the exercise regimen outlined here, fifteen of the seventeen showed improvement. Of these fifteen patients, eight became completely asymptomatic, both subjectively and objectively; six retained only an insignificant amount of synovial thickening; and one finished the exercise program with a small amount of fluid still present in the joint. This patient had had a meniscus removed from the same knee prior to Army service, following which there developed a chronic synovitis, with marked thickening and induration of the synovia. Before the exercise program was instituted in meniscectomy cases, exercise in the gymnasium was started three or four weeks postoperatively, in an attempt to redevelop quadriceps power in these patients by the conventional methods,—such as stairclimbing and bicycling. On this routine, the hitherto smooth postoperative course of rapidly subsiding synovitis was not only interrupted, but in many cases there was a marked exacerbation of synovitis, which usually subsided as soon as the patient was taken off the weight-bearing exercises. It was then found that, when these same patients were given only non-weight-bearing exercises, synovitis did not recur, and the synovitis, which had previously developed, subsided during the course of exercise. It must be assumed that there is some factor in the weight-bearing exercises that produces synovitis, and that this factor does not exist in the non-weight-bearing exercises. These findings can be explained on the basis of relative knee instability. The quadriceps muscle is as important in maintaining knee stability as are the cruciate and collateral ligaments; and, when this muscle group is atrophied and weak, the maintenance of stability rests almost entirely on the

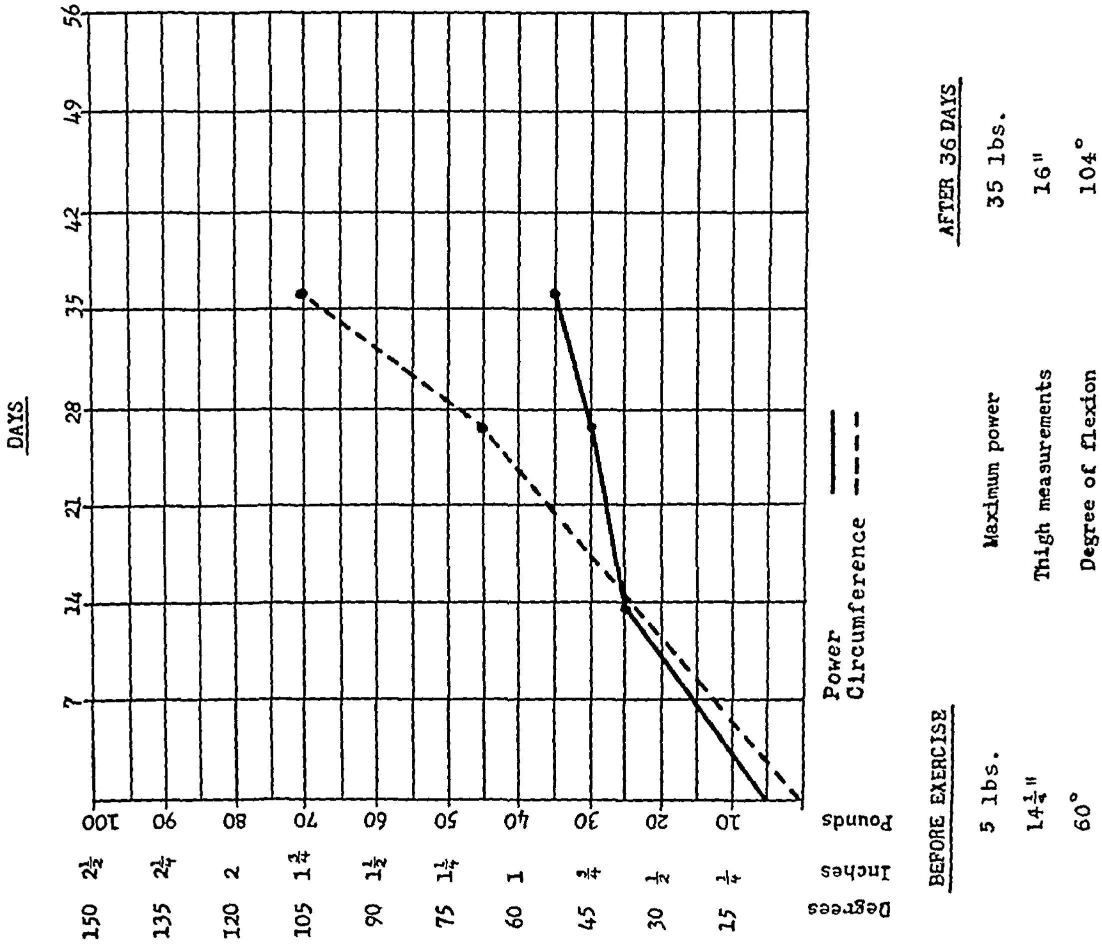

CHART II

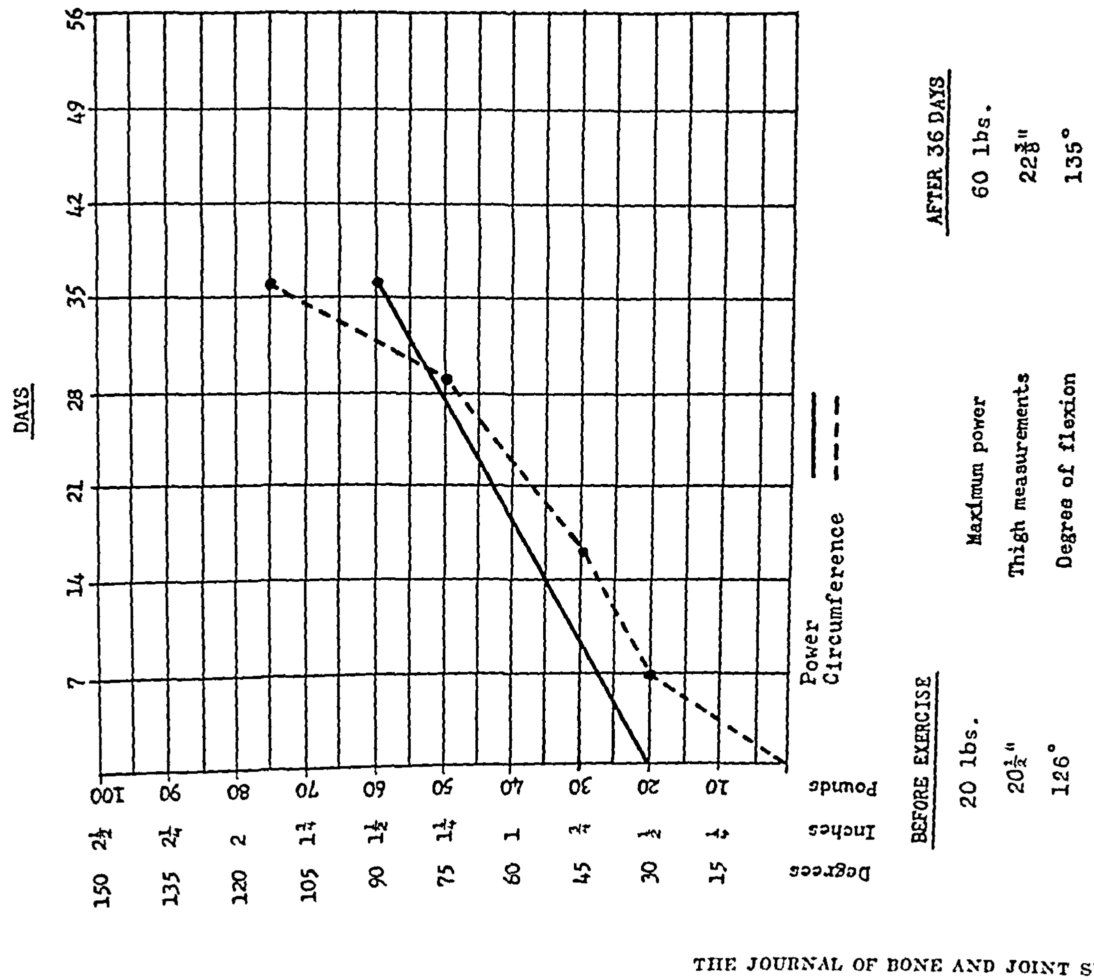

CHART I

ligaments. The ligaments alone cannot maintain as high a degree of stability as when aided by the quadriceps muscle. When, as in cases of meniscectomy, quadriceps power is low, there is abnormal motion in the knee joint. It is this abnormal motion that is indirectly responsible for the development of synovitis in weight-bearing exercises. The twisting, turning, and jarring of the weight-bearing exercises in a relaxed joint probably traumatizes the synovia by nipping and stretching, causing a synovitis; whereas, if the exercises were performed sitting down, the motion in the joint would be in a normal plane, and the knee would not be under the strain of the body weight. Thus instability is precluded as a source of synovial irritation during convalescence.

Fractured Femora

Charts I and II show the gains made by two patients with fracture of the femur, after they had been discharged from general physical therapy. These two represent the average response in twenty cases of fracture of the femur. The gain in circumference for those patients who had obtained flexion of the knee to approximately 90 degrees ranged from one to two inches in the first four weeks of exercise. When flexion was less than a right angle, the gains were not so rapid, since the quadriceps could not be as thoroughly exercised through this limited range. A few patients who worked exceptionally hard increased their thigh measurements by two to two and a half inches in from six to eight weeks.

Frequently, after immobilization, the muscles of the thigh, especially the quadriceps group, are hard in consistency, due to fibrotic changes, which have occurred during the period of inactivity. Immediately after these strenuous exercises have been begun, these same muscles begin to soften, and in a few weeks have regained their normal consistency. This rapid softening of hard fibrotic muscles has been one of the most interesting aspects of this program, and has further substantiated our belief that weakened, fibrotic, atrophic muscles should not be "pampered" because of their subnormal condition, but should be exercised against heavy resistance. In the case of one patient who was immobilized for fourteen months, the thigh muscles of the injured leg showed atrophy of two inches, and had the consistency of hard rubber. After two months of exercise, the thigh had increased one and one-half inches in circumference, and the consistency was that of normal muscle.

Restoration of Motion

Attaining a normal range of knee-joint motion, following immobilization incident to a fracture of the femur, is often a difficult and perplexing problem. After prolonged immobilization, especially in fracture of the lower third (more especially those involving the femoral condyles), there is often a marked limitation of flexion. When some of these patients first begin physical therapy (consisting of heat, massage, and exercises with mild forcing) they often rapidly regain flexion of about 30 to 50 degrees, and then during weeks and months of a similar routine make no further progress. For these cases a leg-exercising apparatus (Fig. 8) has been constructed.

Leg-Exercising Apparatus

This machine was designed to allow the patient to exercise the leg against resistance in a position most conducive to the bending of the leg by such resistance. Because the patient himself is in complete control at all times of the amount of resistance, and can remove and apply resistance as pain and fatigue dictate, he will allow the leg to flex more than if a physical therapist were applying the same amount of resistance by hand. The patient cannot control the pressure or movements of the operator, and will not relax the antagonistic muscles sufficiently to permit the knee to bend to a point of discomfort. However, if he himself can apply the resistance, he will allow the knee to bend to the point of pain, without complaint. In order to attain flexion in stubborn cases, it is necessary to exercise to the point of discomfort, even pain.

The apparatus is used in the following manner: The exercise begins with knees com-

pletely extended (Fig. 9). The pins labeled *A* are removed, thus freeing the weight, which is then slowly lowered, as the knee is allowed to flex. The downward direction is continued as far as pain or tightness in the joint will permit. The knee is then completely extended; there is a momentary pause, and it is lowered again. The cycle is repeated ten to twenty times. The pins are replaced, the patient rests for a minute or so, and the cycle of ten to twenty repetitions is repeated two or three times.

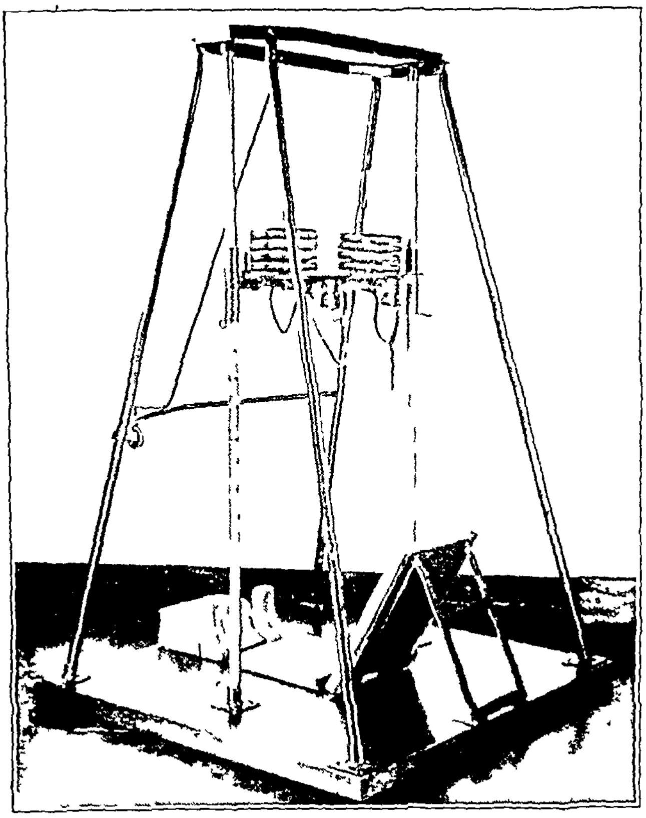

FIG 8
Leg-exercising apparatus.

Twenty patients with fracture of the femur have been given these exercises on this apparatus. All twenty had been discharged from general physical therapy as having attained maximum flexion. By the use of this apparatus, the average gain in flexion was 25 degrees in thirty-two days However, these figures include eight patients who had fractures about the femoral condyles or who had had prolonged immobilization because of slow union or refracture. They showed an average gain of 21 degrees in forty-two days. Twelve patients with uncomplicated fracture of the middle and upper thirds showed an average gain of 27 degrees in twenty-one days, a considerably more rapid rate of gain than tha of the group first mentioned. Two of th

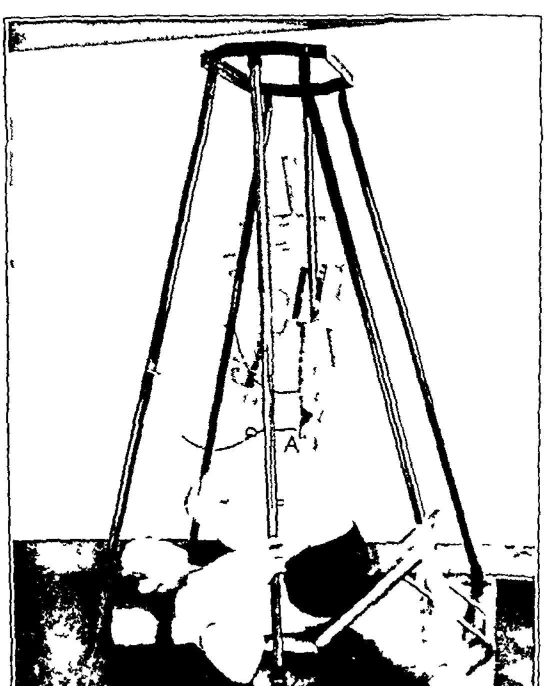

FIG. 9
Leg-exercising apparatus being used to regain flexion. The pins (*A*) fit into the metal guides at different levels, to limit downward motion of the central plate.

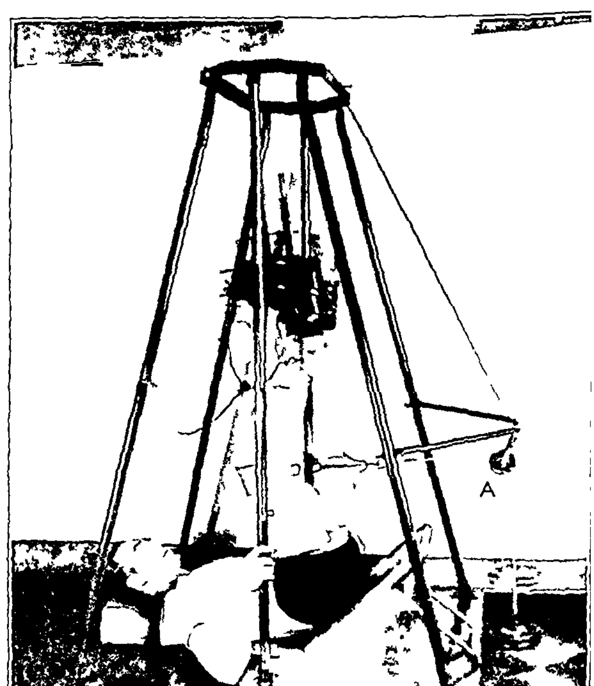

FIG. 10
Leg-exercising apparatus, showing use of the pulley system (*A*) to increase knee-joint extension.

twenty patients were treated by manipulation under anaesthesia in an attempt to increase knee-joint motion; one gained 6 degrees as a result of manipulation; in the other, no increase in flexion could be attained. Both were then placed on this apparatus; the former gained 33 degrees more flexion, the latter 20 degrees. It must be emphasized that the gains in flexion recorded in all twenty cases were made after these patients had received the customary physical therapy for weeks, sometimes months, and had been discharged because no further progress could be made. Constant bending in the form of active heavy-resistance exercises will often produce more flexion than can be accomplished by a single or repeated manipulation. In a few cases, this strenuous flexion of the knee has produced slight swelling of the joint, but in no case has there been effusion. The swelling and soreness which sometimes develop usually subside by the next exercise period.

This apparatus can also be used as a muscle developer with increasing amounts of resistance, after the patient has obtained a good range of motion. When the machine is used for muscle developing alone, the same principle of exercise and method of increasing resistance are used as for the quadriceps exercises. When used for increasing flexion, the amount of weight that can be pushed back into complete extension ten to twenty times with moderate effort is employed.

Three patients who had flexion contractures of the knee rapidly regained complete extension by working on this apparatus. The pulley system (Fig. 10, *A*) brings pressure to bear immediately above the patella by means of the leather cuff. The pressure is directed towards extension. On each repetition, as the knee reaches its maximum extension, the cuff aids the thigh extensors in effecting further extension. Strenuous quadriceps exercises were also given in these cases.

If the injury was a simple fracture of the patella, or if the lower pole of the patella had been removed, the return of motion, strength, and size was usually rapid. However, if the patella was highly comminuted, or if there developed chondromalacia following fracture, the high-resistance exercises usually caused much pain, and occasionally fluid and swelling, and had to be abandoned.

After the immobilization period following dislocation of the patella, these exercises were begun and a rapid return to normal was noted. By building an exceptionally powerful vastus medialis, it might be possible to prevent redislocation of the patella, when the dislocation was due chiefly to weakness of that muscle.

Two patients had chondrectomies for chondromalacia of the patella; following operation, both patients had moderate synovitis of the knee. In each, the synovitis subsided, and smoothing of the patellofemoral articulation occurred as a result of these exercises.

There were many patients with soft-tissue wounds about the knee and thigh. In these, loss of flexion or extension, due to muscular weakness, scarring, or both, was the usual problem. In many cases, where the loss of active motion was a result of muscular weakness, due to loss of muscle substance, the remaining muscle tissue could be overdeveloped sufficiently to compensate for the lost tissue, thereby restoring almost normal strength to the extremity.

Many patients had a limited range of motion because of scarring about the knee joint. Unless bound hopelessly to bone or other deep structure, these scars in most instances underwent remarkable softening, allowing for normal joint motion. The constant flexing in the leg-exercising apparatus (Fig. 8) was sufficient in many cases to restore flexion to normal. The quadriceps exercise usually rapidly restored enough quadriceps power to make possible complete extension.

Results following removal of foreign bodies from the knee were similar to those in the meniscectomy patients, unless there had been considerable joint damage.

In order to gain full extension following patellectomy, it is essential to have a powerful quadriceps. We have used this program of heavy-resistance exercises in only two of these cases. The patients rapidly obtained complete extension, without development of

Fig. 11
Adductor exercise.

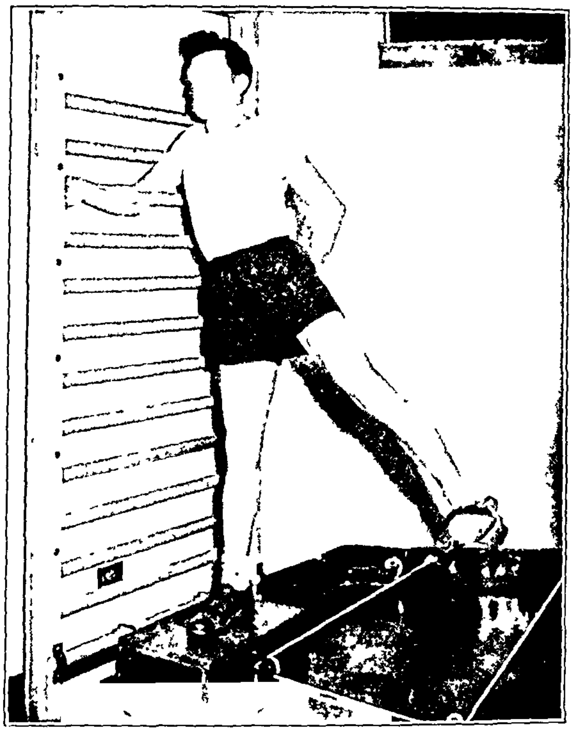

Fig. 12
Abductor exercise.

synovitis; and quadriceps power was restored to within 90 per cent. of that in the unaffected extremity.

When quadriceps power has increased sufficiently to permit weight-bearing exercises, the patient is given heavy-resistance exercises for the other muscles of the extremity.

DEVELOPMENT OF OTHER MUSCLES OF BODY BY SAME EXERCISE PRINCIPLE

The following are some of the other exercises we have used in redeveloping other muscles of the body by the same principle. The type of apparatus, however, varies consid-

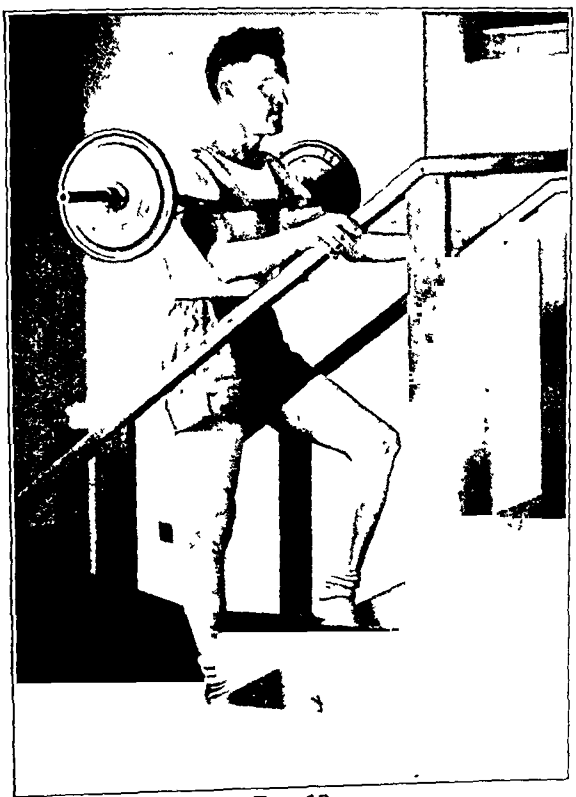

Fig. 13
Stairclimbing exercise.

Fig. 14
Ankle exercise. Resistance can be added at points *A*, *B*, *C*, and *D*, thus giving resistance in dorsiflexion, plantar flexion, eversion, and inversion, respectively. This apparatus has 180 degrees of motion in all four directions, thus also making possible rotary ankle motion.

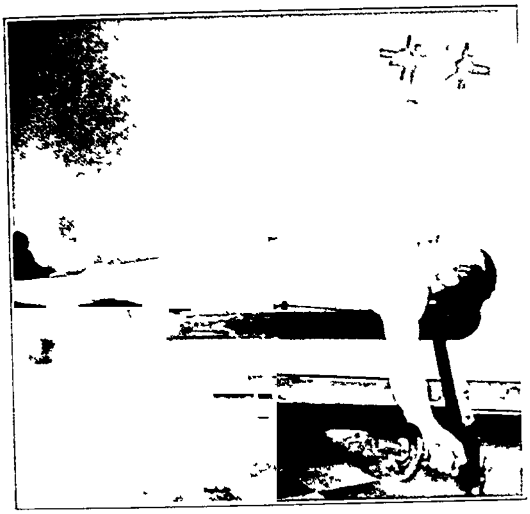

FIG. 15
Pectoral exercise. Arms may be kept straight or slightly bent at the elbow.

FIG. 16
Supine press.

erably, and is designed specifically to obtain the desired results. The repetitions, method of weight increase, frequency and length of workout are exactly the same as described for the quadriceps exercises.

I. *Lower Extremity*

A. *Adductor Exercise.* This exercise is shown in Figure 11.

B. *Abductor Exercise.* See Figure 12.

C. *Hamstring Exercise.* This is an extremely important exercise, and should be diligently performed, especially by patients attempting to regain flexion in stiff knees.

D. *Stairclimbing Exercise.* This exercise is not used to develop the quadriceps; it is not used at all, until the patient has built nearly full quadriceps power by the use of previously described quadriceps exercise. Resistance is added to a metal yoke, and the patient goes over and back five times with one weight, rests a minute or so, adds more weight, and then repeats. By use of the yoke, the hands are free to grasp the rail (Fig. 13). This exercise was thought necessary because, even though a patient may have good quadriceps power, he may still have some difficulty in stairclimbing, if all the other muscles involved are not proportionately developed. The exercise develops, in the low-repetition, high-resistance manner, all of the muscles involved in stairclimbing.

E. *Calf Exercise.* The resistance in this exercise is applied by adding weight to the yoke. The use of the yoke permits the hands to remain free, and the patient can use his hands to steady himself, and maintain balance by grasping a bar in front of him. As strength increases, more weight can be added; and, as ankle-joint motion increases, the wooden block can be made higher.

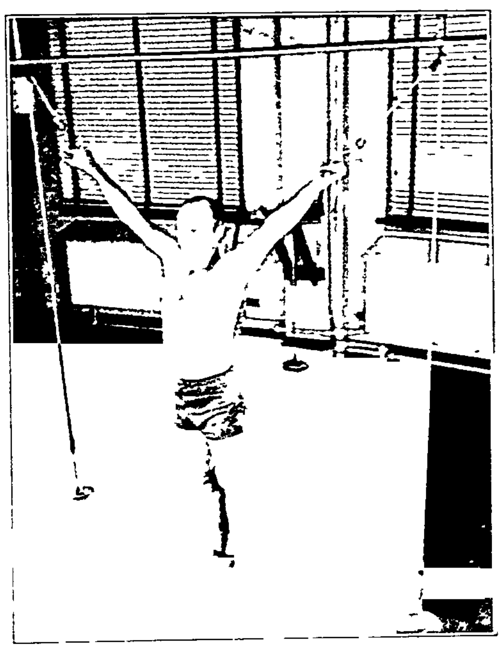

FIG. 17
Shoulder-pulley exercise

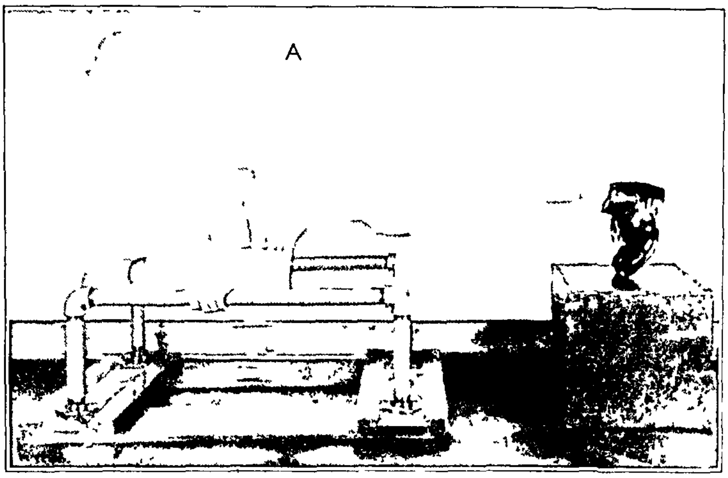

FIG. 18
Parallel bars. Resistance is added to the weight pan (*A*), strapped to the patient's back. The bars can be slid further apart as power and motion increase.

F. *Ankle Exercise.* The apparatus shown in Figure 14 was devised to exercise the ankle in both dorsiflexion and plantar flexion, in eversion and inversion. Resistance may be added to the hook at *A, B, C,* or *D*. The apparatus is also used to help restore ankle-joint motion.

II. *Arm and Shoulder*

A. *Pectoral Exercise.* Amazing hypertrophy of the pectoral muscles can be attained in two or three weeks through the practice of this exercise (Fig. 15). Two patients, who sustained machine-gun-bullet wounds through the axilla with resultant damage to the pectoralis major and limitation of abduction because of scar tissue, were able to loosen the scar sufficiently to obtain a complete range of shoulder motion by use of this exercise. In both cases, after a month of exercise, the patients had increased the size of the atrophied pectoralis so that it was larger than the corresponding uninjured muscle.

B. *Deltoid Exercise.* This is well known.

C. *Biceps Exercise.* This is an important exercise, as there exists usually an inch or so of atrophy of the arm following immobilization for fracture of the humerus. It is important, not only because it redevelops biceps power, but also because of its value in increasing elbow-joint motion. We believe that exercising for biceps power will do more to restore elbow-joint motion than all efforts to increase motion of that joint while neglecting biceps power. In this we must except instances where there is a mechanical block or where severe irreparable capsular and pericapsular changes have occurred. On each

FIG. 19
Exercise for external rotators of the arm. The pronator and supinator muscles of the forearm are exercised on the attachment labeled *A*, to which resistance is applied on the weight pan *B*. Resistance for the shoulder exercise is applied to the weight pan *C*.

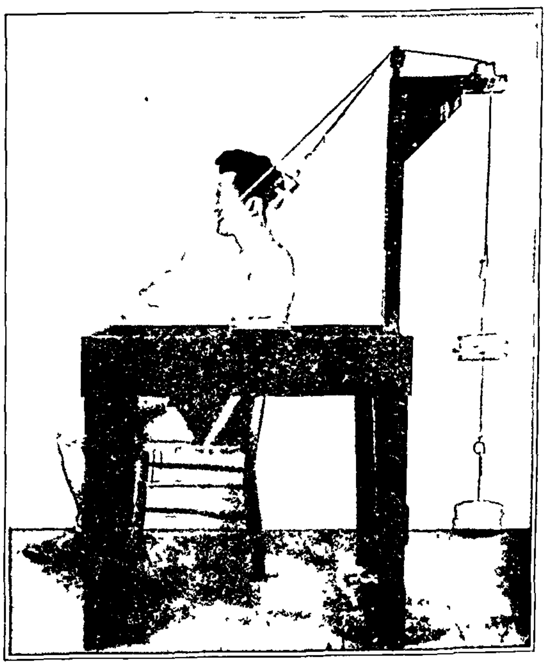

FIG. 20
Exercise for internal rotators of the arm.

repetition the patient should make every effort to obtain as much flexion and extension as possible. Triceps exercises should also be used in conjunction with the biceps exercise.

D. *Supine Press.* See Figure 16 for illustration of the exercise. This is extremely good for loosening up the elbow and shoulder joint.

E. *Pulley Exercise.* Restoring normal scapulohumeral motion following a fracture of the humerus is often difficult. We have obtained, in most instances, good results through use of this pulley exercise, combined with the pectoral, biceps, and deltoid exercises. It is essential that the pulley be an extremely high one, so that the arm can go into complete abduction (Fig 17). On each repetition the arm should be allowed to abduct as far as comfort will permit the weights to pull it; then the arm is brought back to the side, there is a momentary pause, and the exercise is repeated. This is done ten times, more weight is added, and it is repeated another ten times, *et cetera.* An effort should be made to abduct the arm a fraction further on each repetition. This exercise has produced good results, where scapular motion is limited because of fractures of the scapula and large soft-tissue defects. The constant forcing, in the form of active, heavy-resistance exercises, steadily increases the motion of the joint.

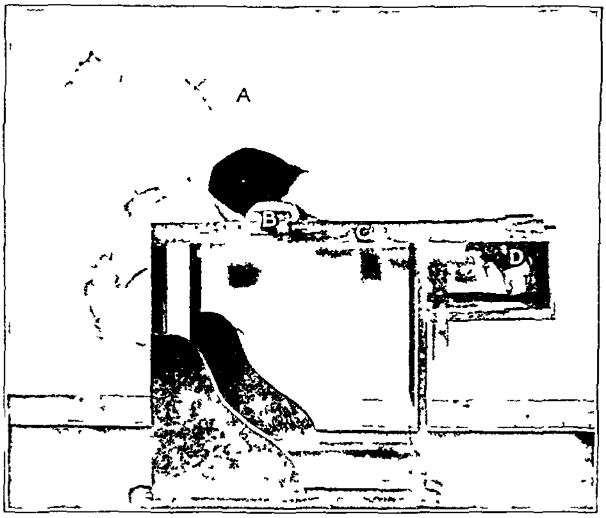

Fig 21

Hyperextension exercise being performed on special back exerciser. Resistance is increased by adding weights to the weight pan *A*. The body rest *B* is adjustable on track *C* to accommodate an individual of any height. The feet are securely immobilized in two iron boots *D* attached to the frame.

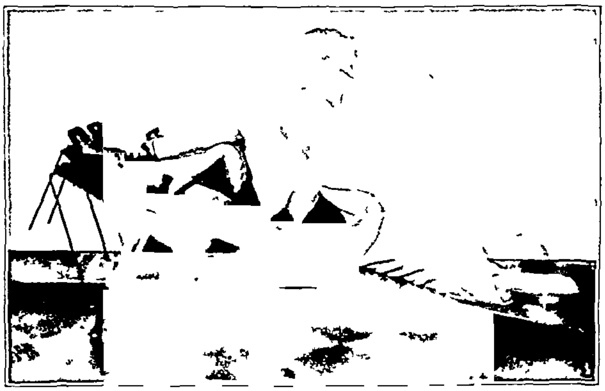

Fig. 22

Abdominal exercise.

F. *Parallel Bars.* This is a good exercise for the shoulder and arm (Fig. 18). Resistance is added to the weight pan strapped to the back. The width of the bars can also be varied.

G. *Arm-Exercising Table.* This table is designed to exercise the pronators and supinators of the forearm, and the external (Fig. 19) and internal (Fig. 20) rotators of the shoulder.

III. *Trunk*

A. *Back Exercise.* Hyperextension exercises are done on the apparatus shown in Figure 21. This apparatus offers several improvements over the method in general use. The weight pan attached to the back makes possible increases in accurately graded resistance. This cannot be accomplished, as was attempted in the old method, by progressively extending the patient farther over the table edge. Our method does not require an operator to hold the patient's feet. The position of the patient is more stable and comfortable; and, since he is not quite parallel to the floor, it is much easier for him to hyperextend more completely.

B. *Abdominal Exercise.* By maintaining the knees and hips flexed (Fig. 22),

more of the load falls on the abdominal muscles and less on the iliopsoas muscle. This makes possible development of the abdominal muscles without concurrent development of the iliopsoas. Since the lumbar spine is flexed by the abdominal muscles and extended by the iliopsoas, the selective redevelopment of the abdominals brings about stronger pelvic control, which is of great value in the treatment of certain back ailments. Many patients who have received injuries to the anterior abdominal wall, with resultant loss of muscle tone and tissue, have exercised on this apparatus with considerable improvement. Graded resistance increases are made by increasing the incline of the board.

Only a few of the exercises actually used have been mentioned. With the equipment illustrated, several hundred different exercises can be worked out. We have shown only a few of those most frequently used, but, in order to conduct exercise programs properly, both for range of motion and muscle power, in a great variety of injuries, a therapeutic gymnasium must be equipped with the apparatus described.

THE THERAPEUTIC GYMNASIUM

The therapeutic gymnasium should not be a place of amusement or for keeping fit. It should be a place in which a treatment, prescribed after thorough examination by the medical officer, can be properly given. The gymnasium should be supervised by the medical officer, but it is not necessary that he actually attend the exercises. The gymnasium should be planned and constructed as specifically for its purpose as is the operating room for its purpose. All pieces of exercise apparatus should be designed to produce a desired result in a specific type of case. Accurate notes on the progress of each patient should be made at regular intervals. The patient should work by appointment, and his attendance should be recorded. The appearance of the gymnasium and the working condition of the equipment are very important, for the patient will maintain much more interest in his exercise if the gymnasium is bright, colorful, well ventilated, and well kept. Equipment in poor condition is not only dangerous, but it also disheartens the patient, and makes it difficult for him to perform his exercises.

It is a good policy to work out several different ways of doing the same exercise. This will prevent the patient's losing interest from monotony. The greater the variety of exercises, the greater the patient's interest.

It has been our experience that greater cooperation is achieved, when the patient understands the nature of his injury. Anatomical charts are kept, and are exhibited on the walls, to give him a clear conception of his disability and its location. He also can see what muscles have to be redeveloped or what joints must be loosened up, before he can attain maximum benefits. A chart with the normal ranges of motion for all the joints of the body should be displayed, and the patient should be taught the normal range of the joint upon which he is working. He should become familiar with the measurements of his affected part, the power of that part, and the exact number of degrees of motion present; then, each week, when new measurements are taken, he will know in inches, degrees, and pounds the gains he has made. This will do much toward maintaining the patient's interest.

The instructor should be efficient, thoroughly familiar with each patient's disability, know what he is trying to accomplish in that patient and, above all, display interest in the work. A patient cannot be expected to show any more enthusiasm than the one who supervises his exercise.

CONCLUSIONS

1. Low-repetition, high-resistance exercises produce power.
2. High-repetition, low-resistance exercises produce endurance.
3. Each of these two types of exercise is incapable of producing results obtained by the other.
4. Weakened, atrophied muscles should not be subjected to endurance-building exercises, until the muscle power has been restored to normal by power-building exercises.

5. Restoration of muscle power with return of motion in a limb has been neglected in the past. It is, in most instances, preferable to have a limited range of motion with good power than a normal range of motion with inadequate power.

6. Games and group exercises, as practised in reconditioning programs, are unsatisfactory for producing focal muscle development.

7. In order to obtain rapid hypertrophy in weakened, atrophied muscle, the muscle should be subjected to strenuous exercise and, at regular intervals, to the point of maximum exertion.

8. In cases of meniscectomies and unstable knees, quadriceps power should be obtained by the use of strenuous, non-weight-bearing exercises. Weight-bearing exercises can produce pain, thickening, and fluid in knees, which do not have adequate muscle support.

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POLYMORPHOUS-CELL SARCOMA, THE MALIGNANT PHASE OF GIANT-FOLLICLE LYMPHOMA, WITH GENERALIZED SKELETAL INVOLVEMENT AND MULTIPLE PATHOLOGICAL FRACTURES

Report of a Case

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INTRODUCTION

In 1925 Brill, Baehr, and Rosenthal described a disease entity which was characterized by splenomegaly and generalized lymphadenopathy. The pathological change was one of qualitative and quantitative hyperplasia of the follicles of lymphoid tissue to such an extent that it was called giant-lymph-follicle hyperplasia. This observation was confirmed by Symmers [8] who recognized other instances of the disease. Later, Baker added a case.

Further studies of cases of giant-follicle hyperplasia [1] revealed that the tumor could undergo a malignant transformation, and Symmers [9] has discussed the relation of such a malignant phase to Hodgkin's disease and lymphatic leukaemia. The clinical and pathological features of the disease have been summarized by Baehr,[2] and the roentgen treatment of the tumor has been emphasized by Rosenthal, Harris, and Kean, and by Rubenfeld. The association of giant-follicle lymphadenopathy with various skin lesions was presented by Combes and Bluefarb.

In only one case in the literature, however, was a single pathological fracture encountered. Little mention is made of the ability of polymorphous-cell sarcoma to invade bone. The case about to be reported is of interest from several standpoints. There were at least seven pathological fractures, and the entire skeleton was involved. Numerous laboratory procedures were carried out. The diagnosis was supported by biopsy as well as by autopsy, which revealed changes in the tumor from site to site, so that in different microscopic sections it resembled Hodgkin's disease, reticulum-cell sarcoma, polymorphous-cell sarcoma, and giant-follicle hyperplasia.

CASE REPORT

A. F. (No. B34548), a white woman, seventy-seven years old, was admitted to the New Haven Hospital for the first time on October 17, 1942, and discharged on October 24, 1942. At that time a diagnosis of pathological supracondylar fracture of the right humerus was made. The roentgenograms showed the appearance of metastatic tumor with diffuse skeletal involvement (Fig. 1). Search for the primary site was unsuccessful.

The second admission to the Hospital was on April 22, 1943. At this time the patient had sustained a fracture of the shaft of the left femur by turning over in bed.

The past history revealed that there had been a hard tumor mass on the forehead in the mid-line for the last seven years. This had not been increasing in size. For the last three years swellings in the region of each parotid gland had been noted, but according to the history obtained these had not been increasing in size.

The family history was of interest only in that a sister of the patient was reported to be dying from a cancer of the breast.

On physical examination the essential features, in addition to the fracture of the shaft of the left femur, were those of a hard, conical, regular, mid-line protuberance on the forehead, measuring three centimeters in diameter at its base, and bilateral tumors in the region of the parotid glands, which were firm, irregular, and freely movable, and about four centimeters in diameter. There were some small palpable lymph nodes in the posterior triangles of the neck. These were so small that not much importance was attached to them at that time.

The fractured extremity was placed in Russell traction. Roentgenograms revealed that the basis

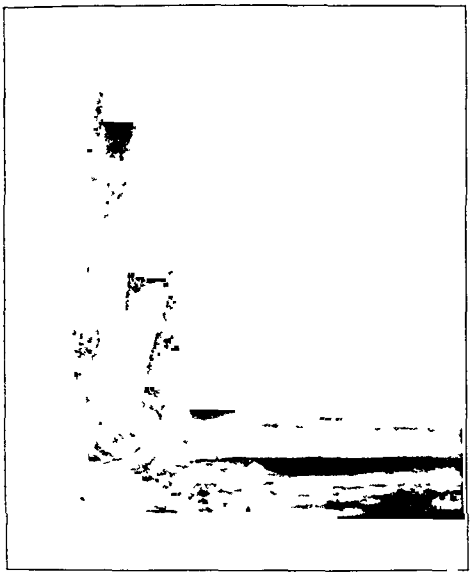

FIG. 1
Pathological supracondylar fracture of the right humerus. Note the destructive process present in the humerus, and particularly in the ulna.

FIG. 2
The healed fracture shown in Fig. 1 Note the progression of the lesion.

FIG. 3
Pathological fracture of the shaft of the left femur A similar process to that seen in Fig 1 is apparent.

FIG 4
The shaft of the left femur, showing the four fractures in various stages of healing

TABLE I

CHEMICAL ANALYSES OF BLOOD SERUM

Date	Calcium (*Milligrams per cent.*)	Phosphorus (*Milligrams per cent.*)	Total Protein (*Grams*)	Albumin (*Grams*)	Globulin (*Grams*)
Apr. 28, 1943	9.37	4.25	5.18	3.49	1.69
Aug. 9, 1943	10.11	4.42	5.34	3.58	1.76
Aug. 16, 1943	9.8	4.30	5.42	3.66	1.76
Sept. 22, 1943	9.77	4.38	5.23	3.55	1.68

for the fracture was an extensive lesion of the shaft (Fig. 3). The entire skeleton was x-rayed, and every bone was found to be involved with the same destructive disease. It was noted that there were healed fractures of the right humerus (Fig. 2), the left radius, and the second lumbar vertebra.

As the first fracture of the left femur healed, there occurred a second pathological fracture well distal to it, because of an increase in the destructive process. During the healing of the second fracture, a third one occurred in between the first and the second, without any undue or unusual trauma, and while the patient was still in traction. The third fracture healed, and a fourth pathological fracture of the same femur occurred while the patient was attempting to sit up (Fig. 4).

Table I shows the values of the serum calcium, phosphorus, the total protein, and the albumin and globulin fractions on repeated examinations. Vitamin D and calcium lactate, given during the period August 11 to November 21, 1943, had no effect on these figures.

A provocative test for the possibility of hyperparathyroidism was carried out, and yielded negative results.

The serum lipoids were normal. The serum acid phosphatase was 1.5 King Armstrong units (normal: 0.5–2.5), and the serum alkaline phosphatase was 7.7 King Armstrong units (normal: 3.7–13.1). Repeated serological tests for syphilis (Kahn and Wassermann) were negative.

Many examinations for Bence-Jones proteinuria were negative.

The blood picture showed a moderate hypochromic anaemia, with a relatively normal differential count (Table II).

TABLE II

BLOOD FINDINGS

Date	R.B.C. (*Millions per cubic millimeter*)	Hemoglobin (*Grams per 100 cubic centimeters*)	W.B.C. (*Thousands per cubic millimeter*)	Polymorphonuclear Neutrophils Non-Segmented (*Per cent.*)	Polymorphonuclear Neutrophils Segmented (*Per cent.*)	Lymphocytes (*Per cent.*)	Mononuclears (*Per cent.*)	Eosinophils (*Per cent.*)	Metamyelocytes (*Per cent.*)	Basophils (*Per cent.*)
Apr. 22, 1943	3.8	11.2	4.3	18	71	9	1	0	1	0
May 29, 1943	3.5	11.5	8.1	3	69	18	6	3		1
June 22, 1943	3.5	9.5	7.9	9	65	23	3	0		0
Oct. 6, 1943	3.25	9.0	6.1	0	72	22	2	2		2

The non-protein nitrogen was twenty-six milligrams per 100 cubic centimeters, and the phenolsulfonphthalein excretion was 75 per cent. in two hours.

During the patient's stay in the Hospital, there was a gradual enlargement of the nodes in the posterior triangles of the neck, as well as of the bilateral tumors in the parotid regions. The conical protuberance on the forehead also increased in size. The spleen and the liver were not palpable, and there was no other enlargement of lymph nodes.

Biopsy of two cervical nodes was carried out. In each there was the characteristic picture of giant-follicle hyperplasia (Fig. 6). Mitoses were seen, and in one area a tendency to invade the capsule was observed.

Biopsy was done on the olecranon, but this showed only thinning of the cortex and some fibrosis of the marrow. Therefore, a second biopsy of bone was carried out, this time in the distal portion of the ulna, a region shown by the roentgenogram to have had marked destruction. This revealed microscopically no more than the section from the olecranon.

The patient had a gradual downhill course, and died before the fourth fracture of the femur had healed.

The essential findings at autopsy were as follows: Lymph nodes were enlarged in the mediastinum, the neck, the peripancreatic region, and the mesentery. The lymphoid structures of the wall of the gastro-intestinal tract (particularly the stomach, ileum, and colon) were also enlarged (Fig. 7). Tumor had infiltrated the pancreas, but both the liver and the spleen were spared. Examination of the cranium revealed that the conical protuberance was composed of tissue which extended inward to involve the dura, but which spared the brain. All of the bones examined were extensively destroyed by the neoplasm.

FIG. 5
The skull illustrates the same process.

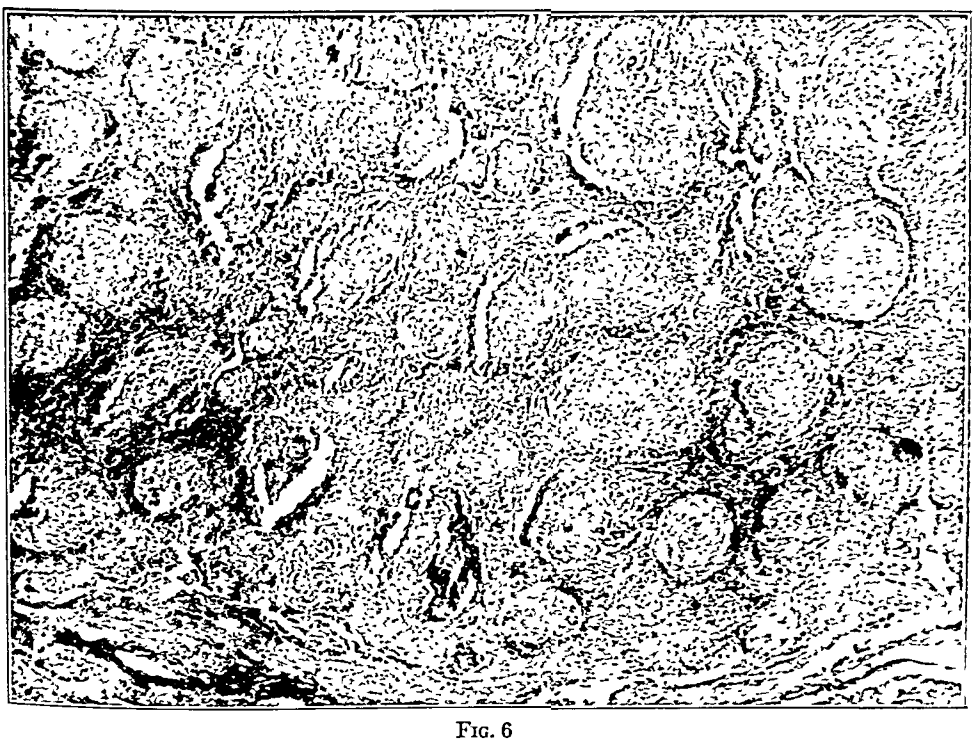

FIG. 6
Section of cervical lymph node with giant-follicle hyperplasia.

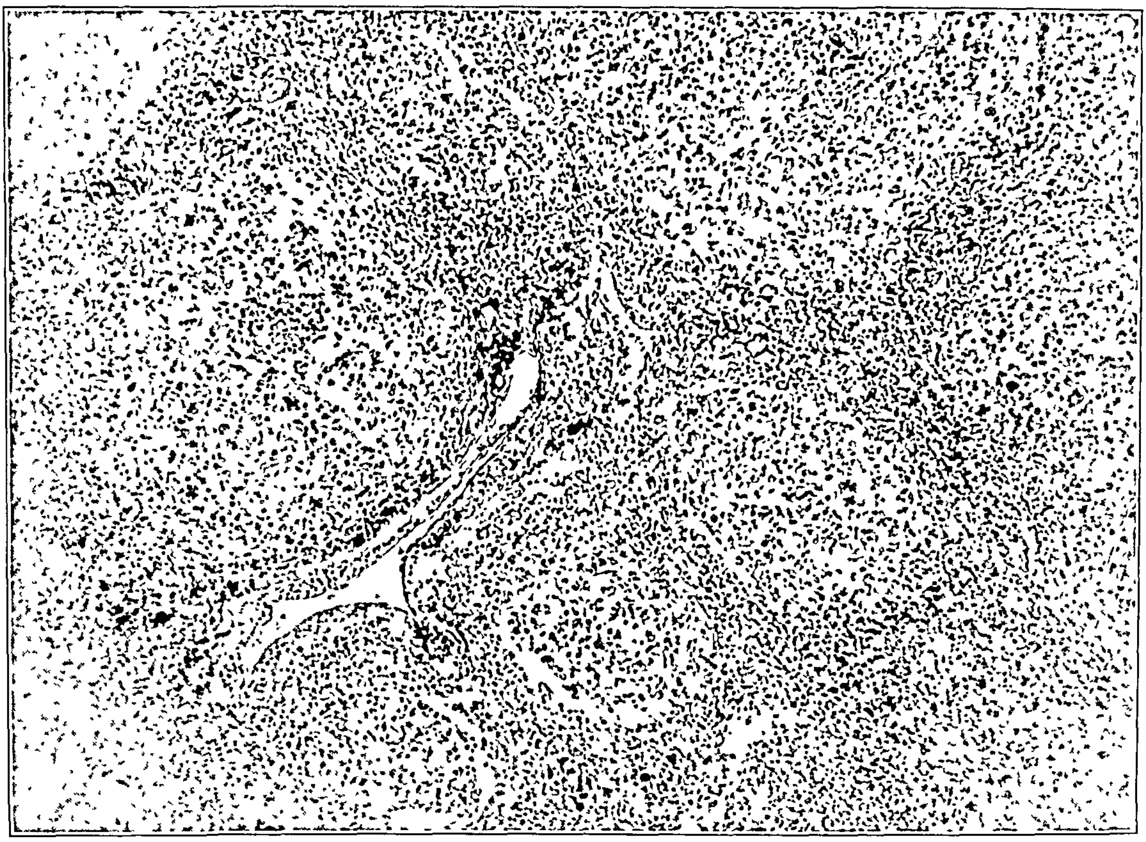

FIG. 7
Section of lymphoid tissue from wall of the stomach. This resembles giant-follicle hyperplasia. Compare with Fig. 8.

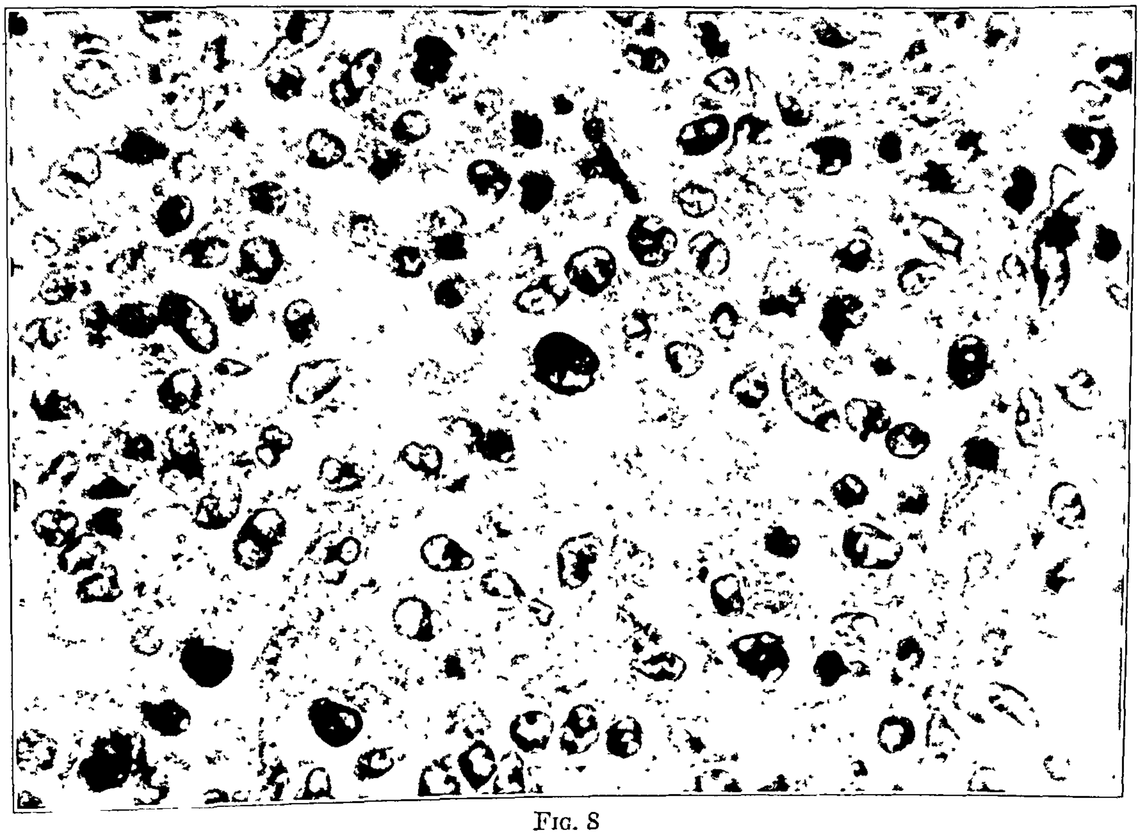

FIG. 8
Section taken from the tumor invading the pancreas. This illustrates the great pleomorphism of the cells.

The microscopic features of the tumor varied in different parts of the body so that various sections examined resembled giant-lymph-follicle hyperplasia. Hodgkin's disease, reticulum-cell sarcoma, and polymorphous-cell sarcoma (Fig. 8).

COMMENT

There were several unusual features in this case. The age was greater than in other cases reported. All bones were invaded. The presenting complaint was a pathological fracture, rather than enlarged lymph nodes. Neither the spleen nor the liver was involved. The tumor presented a histological picture, the predominant characteristics of which varied with the different tissues examined. Numerous laboratory procedures were remarkable for their normal results.

Acknowledgement is gratefully made to H. S. N. Green, M.D., for interpretation of the biopsy, and to Stanley H. Durlacher, M.D., for the autopsy material. Both are members of the Department of Pathology, Yale University School of Medicine.

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SPONTANEOUS BILATERAL FRACTURE OF THE NECK OF THE FEMUR FOLLOWING IRRADIATION

BY CLARENCE H. HEYMAN, M.D., CLEVELAND, OHIO

Numerous cases of fracture of the neck of the femur following irradiation have been reported in the literature. However, since some of these have been associated with trauma, not all can be attributed solely to the effects of irradiation.

It appears that bony union following these irradiation fractures has been rare. Since there are no detailed reports as to the treatment of such fractures, we cannot reach conclusions as to the cause of non-union. It has been suggested that an obliterative endarteritis caused by irradiation was a predisposing factor to non-union, but inaccurate reduction and incomplete fixation may have been the determining causes.

In each of the fourteen cases reported by Dalby, Jacox, and Miller, pain antedated the diagnosis of fracture by some months, with an average of seven months elapsing from the onset of symptoms until fracture was demonstrated; and, in all but one case, roentgenograms of the femur preceded the diagnosis of fracture by months or years. Fracture of one hip in the case reported by Barden did not occur until two years after irradiation, but it is not clear whether the patient had had pain previously. There is no mention in the cases reported as to whether pain was relieved by fixation of the fracture. It is of especial interest to note that in none of the cases of Dalby, Jacox, and Miller had there been direct irradiation over the femoral necks, nor were lateral portals used over the trochanters.

In 1926, Ewing described five stages of the effect of irradiation on bones. These stages progressed from a reduction of vitality and growth capacity of bone cells and bone-forming function, following moderate irradiation, to a complete necrosis with a long delay in sequestration, following severe exposure. There may be an increased fragility and marked tendency to spontaneous fracture, but under favorable conditions such fractures may slowly heal. Ewing attributes these features to the results of injury and sclerosis of blood and lymph vessels.

FIG. 1-A FIG. 1-B

Roentgenograms of the right and left hips on November 11, 1943. There is no demonstrable abnormality at either hip. Patient had been having pain at the right hip for four weeks, beginning fourteen months after irradiation. She did not complain of the left hip.

The following is a report of such a case:

Mrs Z, sixty years old, was first examined on November 11, 1943 She was complaining of pain at the inner aspect of the right thigh and knee This had begun four weeks previously, following a long trip on a bus There was no history of injury or date of acute onset of pain During June, July, and August, 1942, she had received radium and x-ray treatments for a partially differentiated squamous-cell carcinoma of the cervix On June 6, 1942, she had received radium treatment consisting of 5076 milligrams and millicurie hours, 2700 hours being given to the uterine canal, and 2376 to the cervix She had also received daily x-ray treatments from July 6 to August 10, 1942, consisting of 2200 roentgen units, measured in air, to each of six pelvic fields (four lower abdominal and two lateral fields), delivering 3432 tissue roentgen units to the center of the pelvis, using 200 kilovolts and a Thoreaus filter, at a distance of seventy centimeters, to fields fifteen by ten centimeters

Although the patient limped, she was able to walk without support There was a moderate muscle spasm at the hip, with limited and painful abduction and internal rotation, and a loss of complete extension There was no definite tenderness The physical findings were those present in an early aseptic necrosis of the head of the femur, or the so-called malum coxae senilis Roentgenograms of the hips, however, showed no abnormality (Fig 1) She was advised to limit her physical activities and to return for further observation

The patient was again examined on January 29, 1944, approximately eleven weeks later Pain had become more severe, and muscle spasm was more pronounced There was now moderate tenderness over the posterior aspect of the hip The lower extremity, however, was not everted, and she could raise the straight leg from the table without difficulty, although there was some pain Fracture was not suspected. She was referred to the hospital for bed rest and traction Roentgenograms made there on February 18, 1944, revealed a fracture of the neck of the femur with a calcified band of callus and moderate rotation of the head (Fig 2) There were small and localized areas of rarefaction of bone at the superior portion of the neck of the femur, but otherwise the density of the bone was normal, and not suggestive of aseptic necrosis Metastatic carcinoma was seriously considered However, local examination of the pelvic organs and general examination, including roentgenograms of the chest, revealed no evidence of tumor Therefore, it was thought that the most likely possibility was a spontaneous fracture following irradiation

Under general anaesthesia, a Smith-Petersen nail was inserted on February 22, 1944, without manipulation of the hip Following this, the patient was promptly relieved of pain and muscle spasm She was discharged from the hospital on the twelfth postoperative day, with instructions to avoid weight-bearing, and to begin gentle active exercises of the hip She was having no difficulty with the left hip

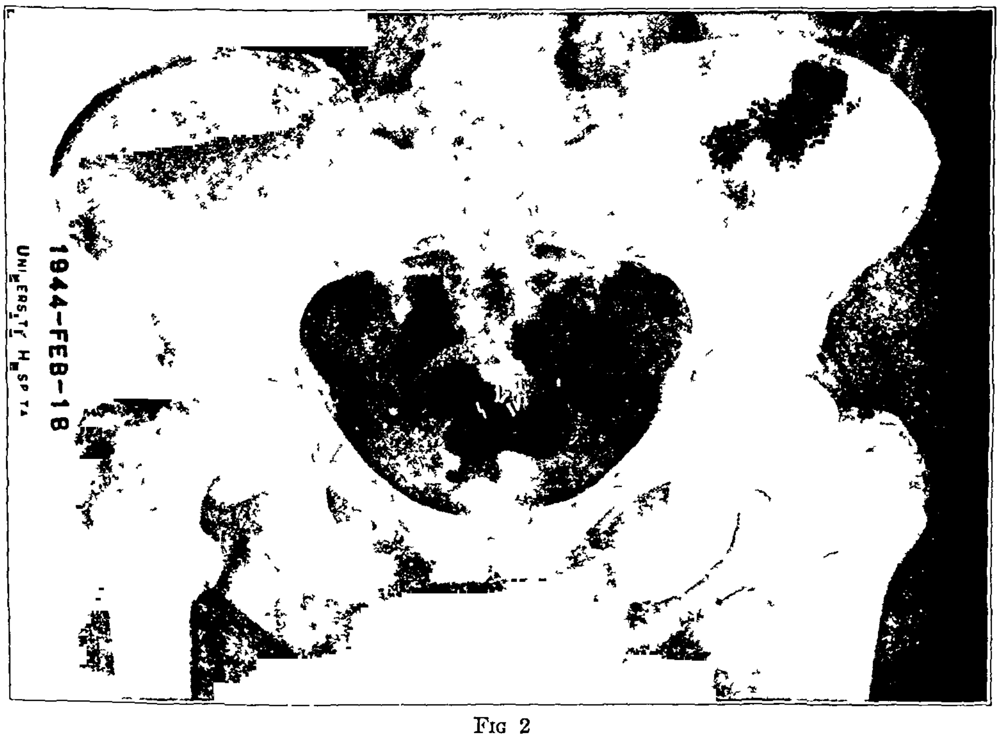

Fig 2

Roentgenogram on February 18, 1944, showing fracture of the neck of the right femur Patient still did not complain of the left hip

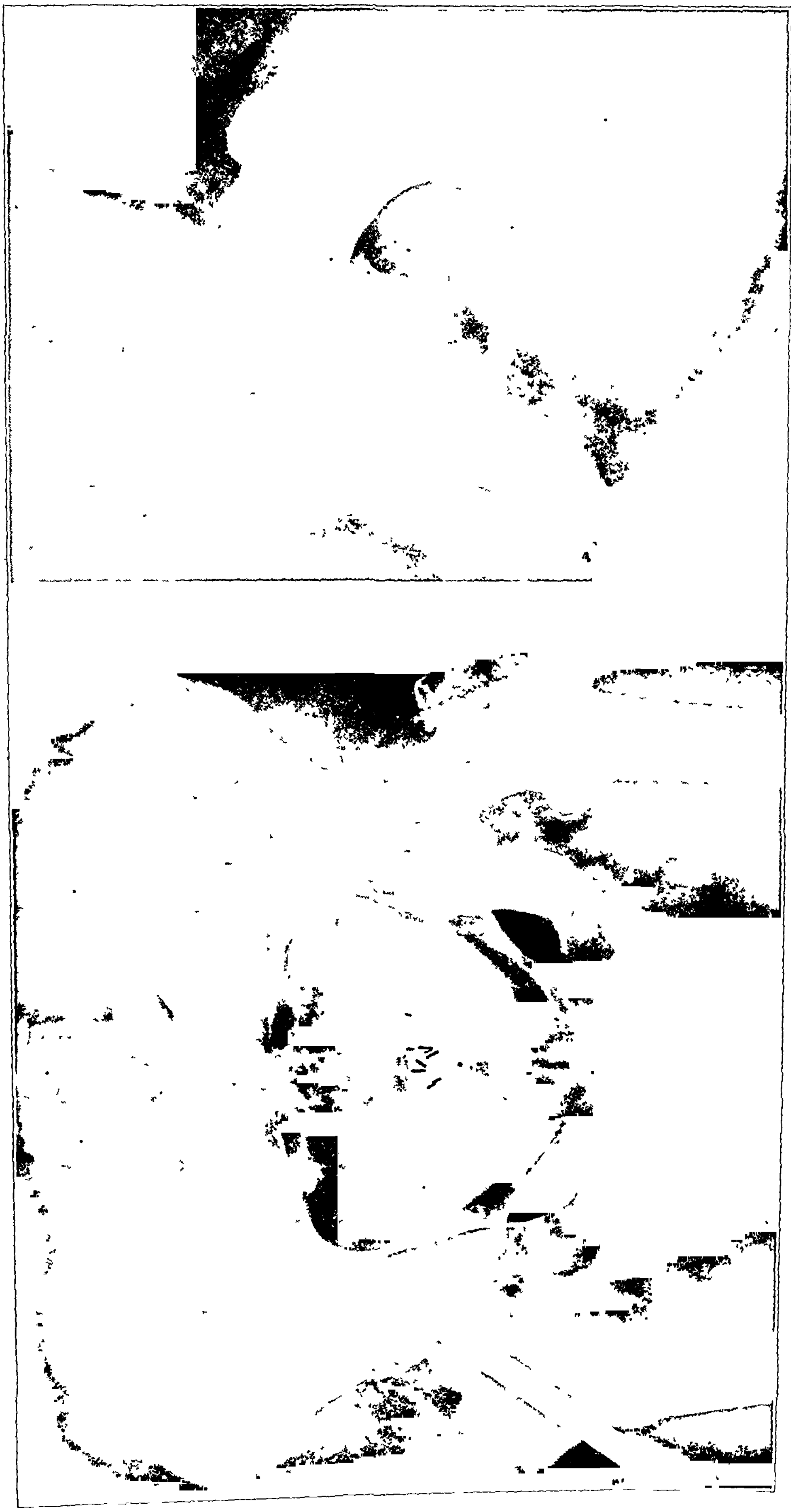

Fig. 3-A

Fig. 3-B

Anteroposterior roentgenograms of both hips and lateral view of left hip on June 24, 1944, six weeks after the onset of pain, showing a fracture of the neck of the left femur. The right hip was then free from pain.

Three months later she complained of pain at the left hip The onset had been gradual, and there had been no injury She was walking with the support of a cane, and was bearing most of her weight on the previously nailed hip, which was now painless There was muscle spasm at the left hip, and inability to raise the straight leg from the table Roentgenograms showed a fracture across the neck of the left femur, strikingly similar to that at the right hip (Fig 3) Since prompt relief of pain had followed nailing of the right hip, and union appeared to be progressing, the left hip was also nailed This was done under general anaesthesia without manipulation, and again there was prompt relief from pain and muscle spasm

When last seen, in March 1945, the patient was free from complaint She had no limp, and had normal motion in both hips except for slightly limited internal rotation She was quite active, could bear full weight without support, and was doing her own housework

Fig 4-A

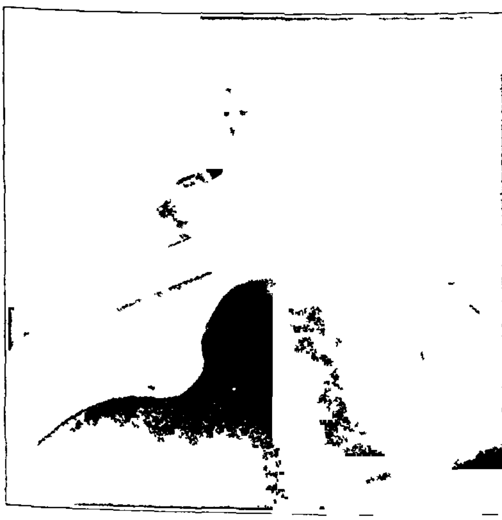

Fig 4-B

Fig 4-C

Anteroposterior and lateral roentgenograms of both hips on December 7 1944 There was bony union and the patient had no complaint at either hip

DISCUSSION

This case apparently typifies the features of spontaneous fracture of the neck of th femur following irradiation. Symptoms did not occur at one hip until fourteen month after the completion of irradiation, and at the other hip until eighteen months afterwar Pain was present in each hip at least four weeks before roentgenographic changes wer demonstrable. It does not seem likely, in the face of negative roentgenograms during th early period of disabling symptoms, that fracture was the determining cause of pain. O the other hand, the patient was promptly relieved following fixation by means of a nai This presents a similarity to the poorly understood mechanism of the "march", or "insu ficiency", or "exhaustion" fracture of the metatarsal bone, os calcis, or neck of the femu It is characteristic of these fractures that there is no specific trauma, and that early roent genograms are negative. Fracture is demonstrable only in later stages, when the nature c the condition is revealed by a band of callus or absorption of bone along the line of fractur

While it is yet too soon to predict the end result regarding later degenerative change of the head of the femur, it appears at this time that bony union has progressed normall Since it is said that non-union is the rule in this type of fracture, it is all the more impor tant that it be treated just as promptly and efficiently as any other fracture of the neck c the femur. Perhaps the likelihood of non-union would then be lessened.

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DISLOCATIONS OF THE CERVICAL SPINE TREATED BY OPEN REDUCTION

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The following report deals with the successful treatment by open reduction of three cases of unreduced fracture-dislocation. In each case, attempted reduction by non-operative methods had failed. In two cases the cause of injury was a motor-transport accident; each patient had been thrown out of a vehicle and landed on his head. In the third case the patient had dived into shallow water.

In the first case there was a unilateral dislocation of the sixth cervical vertebra; in the second, a unilateral dislocation of the third cervical vertebra; and in the third, a bilateral dislocation of the fifth cervical vertebra. Symptoms of cord and root pressure were found in only the first case, the patient having paraesthesia of the upper limbs, and subjective weakness of the right arm and leg. The patients arrived at this Centre from four to sixteen days after injury; attempts at manual reduction had already been made within a few hours after the injury.

In the first two cases further attempts were made at manual reduction under roentgenographic control, with general anaesthesia, but they were unsuccessful. Skull-traction calipers were then applied, and the patient was returned to the ward with initial traction of from ten to fifteen pounds. This was gradually increased to thirty-five pounds, and daily roentgenograms were taken in order to check progress. When it became apparent, after eight to twelve days, that reduction by simple traction was not possible, open operation was decided upon. In the third case it was decided that, in view of the length of time that had elapsed, traction was likely to fail; hence open operation was performed at once. Reduction proved extremely difficult. We now consider that, if traction had been employed for several days before the operation, the reduction would have been greatly facilitated.

OPERATIVE PROCEDURE

The patient was taken to the operating room with the skeletal traction maintained. Pentothal and later intratracheal ether anaesthesia were employed, and the patient was placed in the prone position. After the head and neck had been shaved and thoroughly prepared, a mid-line incision was made; the ligamentum nuchae was split; and the muscles were stripped off the spinous processes and the laminae as far as the intervertebral facets. The dislocated vertebrae were then inspected, and a blunt bone lever was placed beneath the inferior articular facet of each dislocated vertebra, and the facet was carefully levered over the tip of the corresponding superior facet of the vertebra below. During this manoeuvre, strong traction was maintained upon the skull calipers. After reduction the neck was hyperextended; the wound was closed; and the head, neck, and trunk were encased in plaster-of-Paris down to the iliac crests. The skull calipers were then removed.

POSTOPERATIVE TREATMENT

Discomfort lasted for two to three days after the operation, but then the patients were able to sit up in comfort. The sutures were removed at the end of three weeks, and a new plaster cast was applied. Standing was then permitted, and the patients were walking about the ward at the end of the fourth week. After the plaster had been removed, three months after the operation, the first man had a leather collar; and after an-

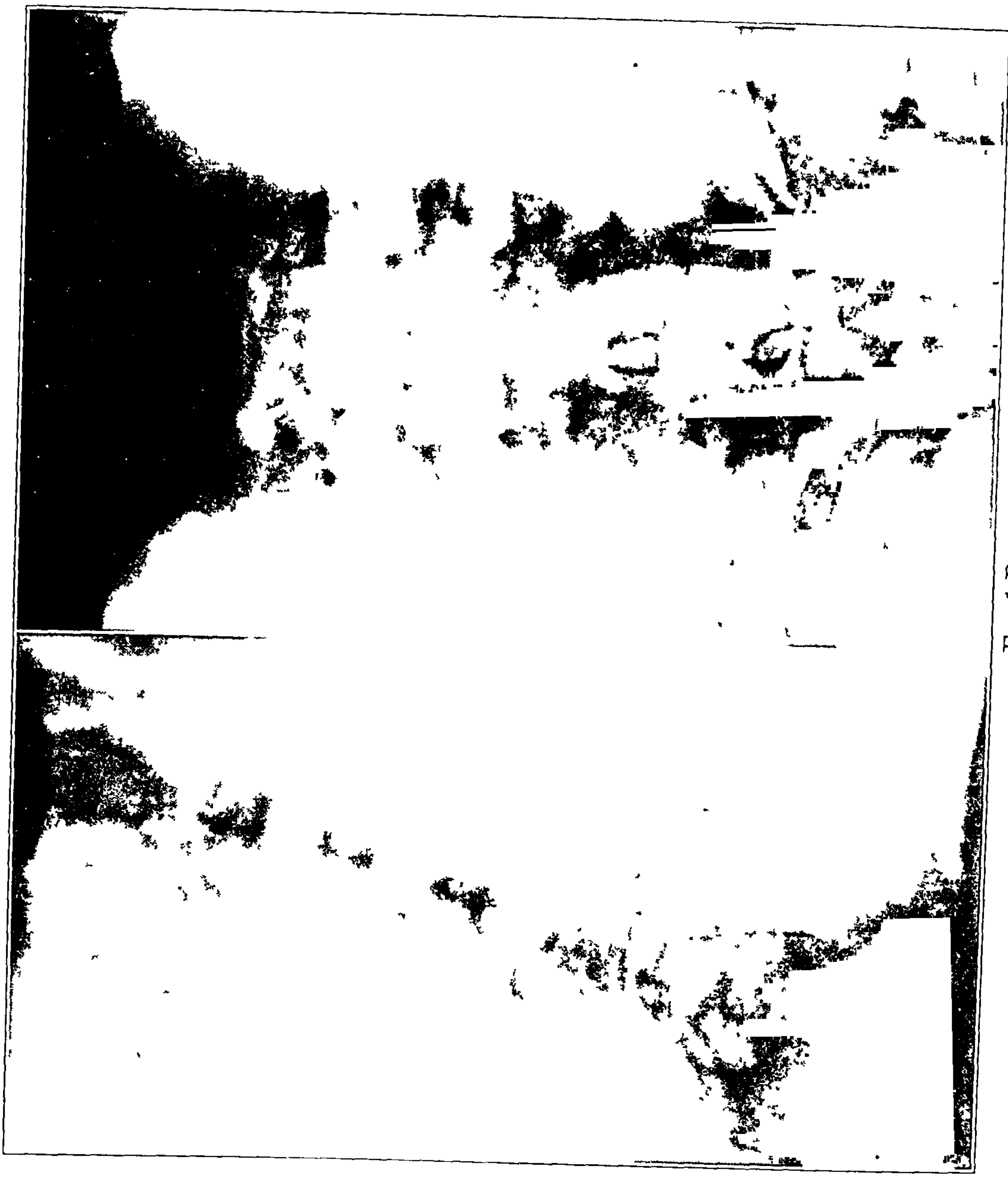

Fig 1-B
After open reduction

Fig 1-A
Case 1 Before open reduction

other month he was returned to duty. The other two patients, wearing plaster collars, were evacuated as ambulatory cases to the United Kingdom, within two months of the operation.

CASE REPORTS

CASE 1. The patient was injured in a jeep accident on March 7, 1944. Manual reduction was attempted under pentothal on the day of the injury, but was unsuccessful. Roentgenogram showed anterior dislocation of the sixth cervical vertebra on the seventh cervical vertebra. On March 12, 1944, a further attempt at manual reduction in this Centre was unsuccessful, and skull-traction calipers were then inserted with ten pounds of traction. The next day traction was increased to twenty pounds, and the head of the bed was raised eighteen inches. On March 15, roentgenograms showed that the dislocation was still present; and on March 18, traction was increased to thirty pounds. However, after two days, roentgenograms showed no improvement in position.

Open reduction was decided upon. The left lower articular process of the sixth cervical vertebra was found lying anterior to the left superior articular process of the seventh cervical vertebra. The vertebra was levered into the correct position, skeletal traction having been maintained throughout. A plaster-of-Paris cast was applied, and the skull calipers were removed. Postoperative roentgenograms showed that full reduction had been obtained. There was no additional injury to the cord.

The patient made a good recovery. He wore a support of plaster-of-Paris for three months, which was replaced by a leather collar.

CASE 2. On September 6, 1944, the patient was injured when he dived into shallow water. Attempted reduction under pentothal on the day of the accident was unsuccessful. Roentgenograms disclosed dislocation of the third cervical vertebra on the fourth cervical vertebra.

Manipulation was attempted on September 10, but was unsuccessful; and skull calipers were then applied with fifteen pounds of traction. Two days later roentgenograms showed that the dislocation was not fully reduced, so the traction was increased to twenty pounds, and the head of the bed was raised eighteen inches. On September 16, reduction was still incomplete, and traction was increased to

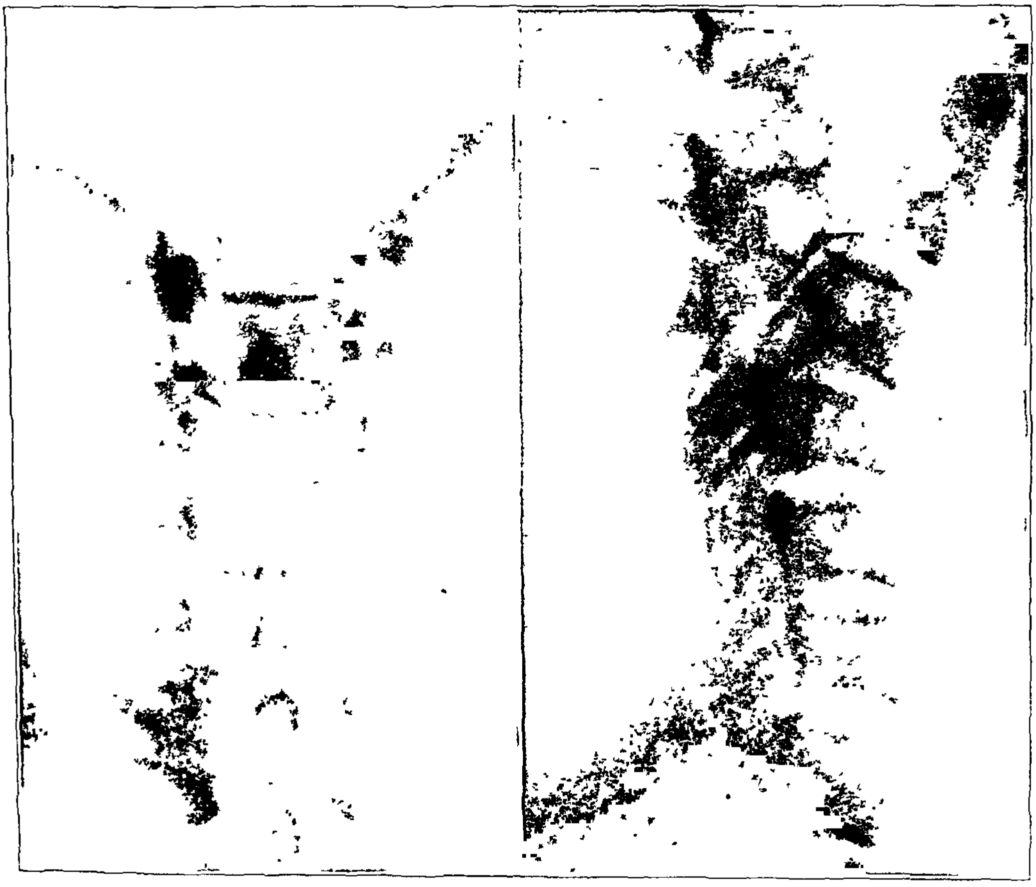

FIG 2-A

Case 2 Anteroposterior view after injury.

FIG. 2-B
Before operation, with twenty pounds of traction applied.

FIG. 2-C
After open reduction. Injury encased in plaster-of-Paris.

thirty pounds. Four days later roentgenograms showed the tips of the articular processes were still interlocking, and traction of thirty-five pounds was applied. On September 22, there was no improvement in the patient's condition, and operation was decided upon.

The lower articular process of the third cervical vertebra on the left side was lying in front of the upper articular process of the fourth cervical vertebra. The right side was not dislocated. The articular process was levered over into position. The tip of the articular facet of the third cervical vertebra had been fractured. A plaster-of-Paris cast was applied, and the skull calipers were removed. The postoperative roentgenograms showed complete reduction.

On November 10, 1944, the patient was wearing a plaster-of-Paris collar, and was evacuated as a walking case to the United Kingdom.

CASE 3. The patient was riding in an armored car when it blew up, and he was thrown from the car, landing on his head. This occurred on August 12, 1944, and the roentgenograms showed a fracture-dislocation of the fifth cervical vertebra on the sixth cervical vertebra.

On September 28, 1944, the patient was admitted to this Centre with the dislocation still unreduced. Operation was decided upon. Skull calipers were inserted for traction. Both of the lower articular facets of the fifth cervical vertebra were lying in front of the upper articular facets of the sixth cervical vertebra, and were firmly locked. The lamina of the fifth cervical vertebra was found to be fractured on the left side. The dislocation was reduced by means of bone levers, with difficulty. The fractured lower left articular facet of the fifth cervical vertebra was broken off during the manoeuvre. At the end of the operation the lamina of the fifth cervical vertebra was lying behind that of the sixth cervical vertebra, and the right posterior intervertebral joint was in normal position. Plaster-of-Paris was applied, and the skull calipers were removed. Postoperative roentgenograms showed complete reduction.

On October 30, 1944, the patient, wearing a plaster-of-Paris collar, was evacuated to the United Kingdom, as an ambulatory case.

UNILATERAL HYPOPLASIA OF LUMBOSACRAL ARTICULAR PROCESSES

A Case Report

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A rare, anomalous, unilateral hypoplasia, with resultant rudimentary lumbosacral articular processes and associated neural arch of the fifth lumbar vertebra, has been recently observed. The writer had never encountered a similar anomaly, and there seems to be no such case described in the literature.

A thirty-year-old white male, Private First Class in the Marine Corps, was admitted to the Hospital, September 18, 1944, complaining of low-back and right leg pain. He had first noticed the gradual onset of this pain five years previously, and there was no history of trauma. Lifting produced pain, as did prolonged walking and running, and occasionally the patient was awakened by the pain. By being careful, he was able to minimize the discomfort, and he felt well enough to enlist in the Marine Corps in January 1943. Following this, although he suffered occasional pain, he did not report to sick bay.

The patient stated that during the four months prior to admission to the Hospital, he had not been free of a constant dull ache. Acute exacerbations of pain in the low back occurred much more frequently, and were aggravated by sneezing, coughing, lifting, and stepping down on either foot. He described the pain as of a locking or catching nature in the low right back, with sharp shooting pain to the right hip and down the posterior thigh to the knee. He had also noted that the right leg tired more easily than the left.

The patient's history revealed that he had had scarlet fever, diphtheria, and pneumonia in childhood, also malaria in 1939. He had had an uncomplicated Neisserian infection in 1936.

Physical examination revealed a right leg limp. The right knee and hip were slightly flexed in the standing position, with the weight resting largely on the left leg. There was some pelvic tilt to the right, as well as body list to the right. Moderate spasm of the bilateral lumbar muscle was present, and there was tenderness to percussion over the lumbosacral and right sacro-iliac areas. Spinal motions were moderately limited in all directions. Forward bending was accompanied by rotation of the lumbar spine to the right. All motions, if forced, caused a "catching" pain in the lumbosacral and the right sacro-iliac areas.

Some atrophy of the right gluteal muscles was present. There was one inch of atrophy of the right thigh, and five-eighths of an inch of the right calf, compared to corresponding points of the left calf. Legs were equal in length. Straight-leg raising was bilaterally equal, and limited to 65 degrees. When leg-raising was forced, pain occurred in the areas of the right sacro-iliac and the posterior thigh. The reflexes and sensations of each leg were normal and equal. The physical examination was otherwise negative.

Routine laboratory tests revealed no unusual findings.

Roentgenographic studies of the lumbosacral spine, including the anteroposterior, lateral, and oblique views, showed rudimentary apposing articular processes on the left, between the fifth lumbar and first sacral segments. The left lamina of the neural arch of the fifth lumbar vertebra was also hypoplastic (Figs. 1, 2, and 3). The corresponding right articular processes and arch seemed normal. The spinous process of the fifth lumbar vertebra appeared normal, although some incomplete fusion of the neural arch of the first sacral segment was present. Narrowing of the fifth lumbar disc was not apparent. Moderate haziness of each sacro-iliac articulation indicated arthritic changes.

The patient was evacuated to the United States, October 27, 1944, as being unfit for field and combat duty.

DISCUSSION

Various developmental anomalies in the lumbosacral spine are well recognized, and not infrequently encountered. However, hypoplasia of the lumbosacral articular processes and associated laminae is rare.

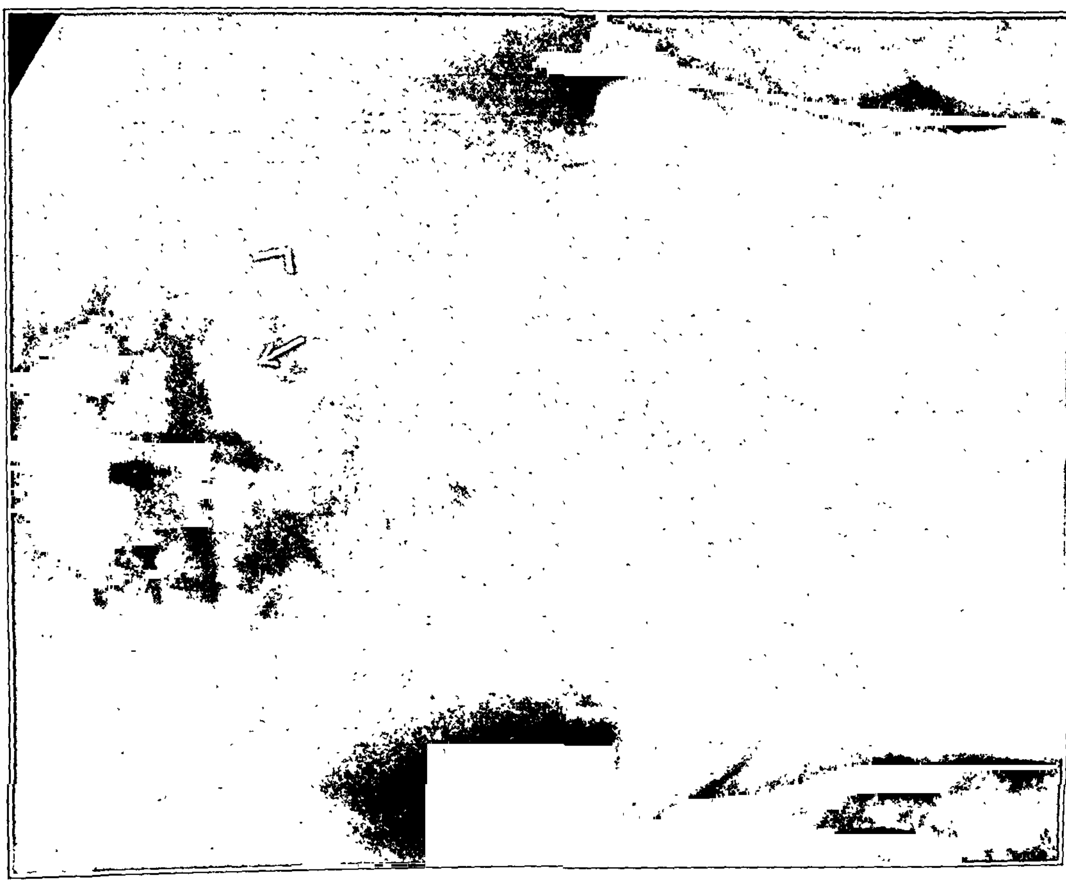

FIG. 1

Unilateral left hypoplastic lumbosacral articular processes (arrow), also hypoplastic left lamina of fifth lumbar vertebra. Note haziness of each sacro-iliac articulation. This is a 15-degree angle projection from below upward. Compare with Fig. 4.

FIG. 2

Oblique view, showing normal right lumbosacral articular processes (arrow).

Fig. 3

Oblique view, showing hypoplastic left lumbosacral articular processes (arrow).

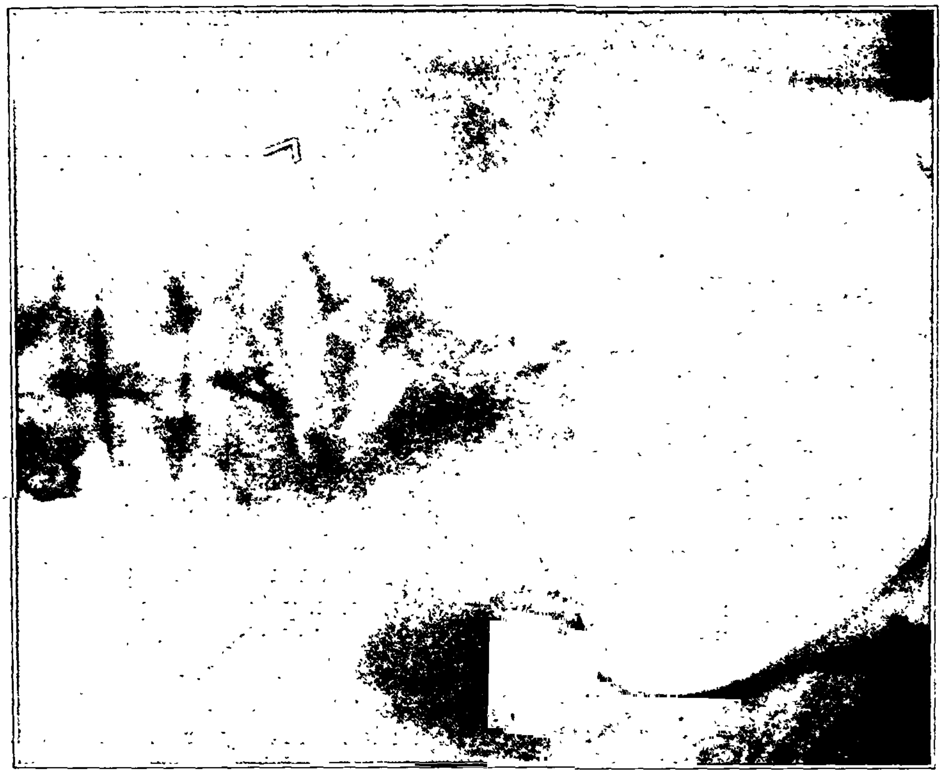

Fig. 4

Routine anteroposterior view which does not show well the left lumbosacral deformity because of overlapping shadows. Compare with Fig. 1.

Ossification of each half of a neural arch, including the articular processes, is usuall from one center. Variation occurs in the form of two primary centers of ossification ir stead of one for each half of the neural arch, especially for the fifth lumbar. The two cer ters, one for the anterior and one for the posterior portion of each half of the arch, ar joined by a cartilaginous plate, and later bony fusion occurs in that portion of the arc between the superior and inferior articular processes.

In the present case, the anterior portion of the left half of the fifth lumbar arch—namely, the pedicle and the superior articular process—appeared normal; while the poste rior portion, including the lamina and the inferior articular process, was underdevelope Thus, it is likely that there were two centers for the left half of the neural arch, the on for the posterior portion being hypoplastic.

Explanation of the rudimentary left articular process of the sacrum appears to li either in the hypoplasia of the center of ossification for the left half of the sacral arch, c in the underdevelopment due to the lack of stimulus from an apposing normally develop ing inferior process of the fifth vertebra. The latter appears likely, as the two apposin processes are very small and rudimentary, and correspond in size, shape, and approxima tion.

A routine anteroposterior roentgenogram did not show the deformity well, whic might have been overlooked because of overlapping shadows (Fig. 4). However, with projection at a 15-degree angle from below upward in the anteroposterior plane, it wa well seen (Fig. 1). Lateral views did not disclose the deformity, but the hypoplastic proc esses and laminae were well seen in the right and left oblique views.

The moderate arthritic changes of each sacro-iliac joint were assumed to be of trau matic origin. There was no evidence in the history or physical examination which coul justify the assumption that the arthritis was due to an inflammatory or infectious condi tion.

One of the striking features of this case is that the patient suffered no pain on th side of the anomaly, but he had right low-back pain which was apparently due to the ab normal stress and strain placed upon the right low-back muscles, fasciae, and ligament

AN UNUSUAL TRAUMATIC CORTICAL LESION OF BONE

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The combination of giant cells and fibrous tissue forms the basic histological pattern for several distinct pathological lesions of bone. These lesions may involve the medulla or the cortex, and, in rare instances, may bear a direct relationship to trauma. They include such varied, yet possibly related, entities as benign giant-cell tumor, osteitis fibrosa cystica, ossifying hematoma, fibrous dysplasia of bone, and non-osteogenic fibroma. This entire group has been open to a wide variation of pathological interpretation, and "conceptions regarding their nature have ranged from that of simple repair or frank infection on the one hand, to true neoplasm and outspoken malignancy on the other." [4]

The following case presents a lesion, apparently traumatic in origin, in which the reaction of the bone to the injury has produced an unusual pattern of giant cells and fibrous tissue, a pattern which simulates, in many respects, a tumor of the benign giant-cell type.

CASE REPORT

CASE No. 114408. The patient, a sixteen-year-old white school boy, was first seen by one of the writers (J.J.C.) on April 7, 1944. At this time the boy complained of pain in the right leg, which had been present since March 28, 1944, when he had slipped on the steel tread of the stairs at school, and had twisted his ankle. Following this accident, he had been immediately taken to the Lynn Hospital, where roentgenograms were made of the right foot. As no fracture was noted, the foot was strapped, and

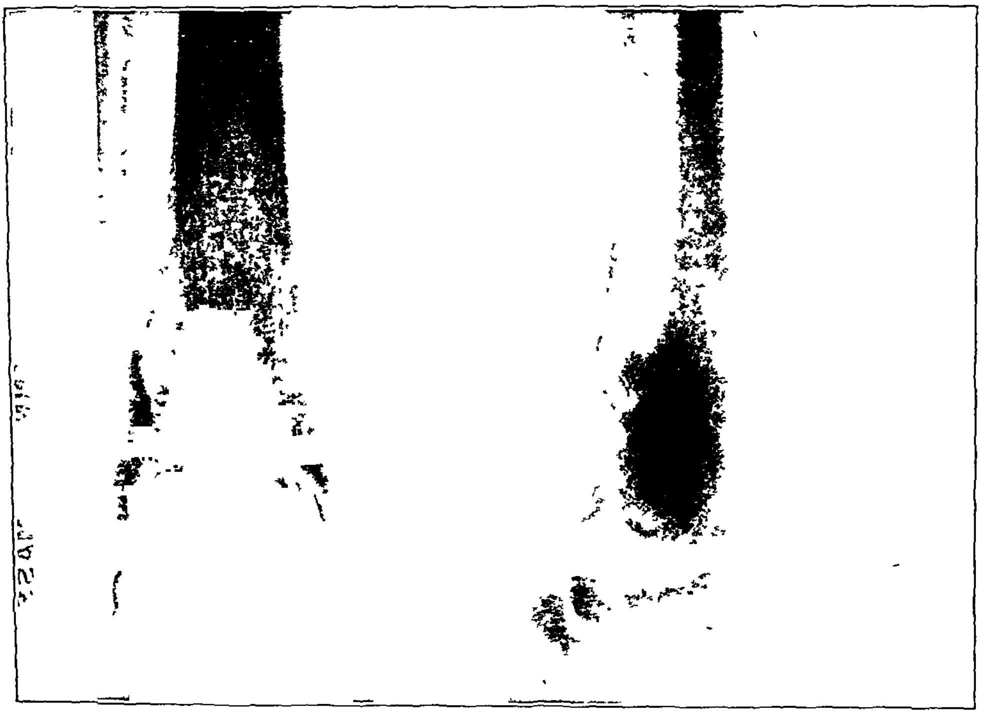

FIG. 1

Roentgenograms taken on the day the patient twisted his ankle, and approximately six months following the original hockey injury. The location of the lesion is well shown. It appears to be entirely limited to the cortex, which is being destroyed. There was sharply localized tenderness at this point.

FIG. 2

A more detailed view of the original cortical lesion. *The medulla is not involved,* and the periosteum likewise shows no reaction.

the patient was told to report to the Clinic in two days. He did not return until April 7, ten days later, for removal of the strapping. At this time pain was still present, and *on re-examination of the roentgenograms,* a peculiar small defect was observed in the bone on the lateral aspect of the lower right tibia. Closer questioning revealed that this area had sustained previous injury approximately six months earlier, when, while playing hockey, the patient had been struck by the puck on the outer side of his right ankle. He had not been incapacitated by this injury, although he had limped for several days.

The patient was admitted at once to the Lynn Hospital for observation.

The examination showed oedema of the lower third of the right leg, with an acute and sharply localized area of tenderness over the lateral aspect of the lower right tibia, about three inches above the ankle. The temperature was normal, and physical examination was otherwise negative. Roentgenographic examination of the right lower extremity revealed a localized destructive lesion in the cortex of the lower lateral aspect of the tibia, about two or three inches (5 to 7.5 centimeters) above the ankle joint. The lesion involved the cortex only, and resembled somewhat a Brodie's abscess or a cortical cyst. There was no evidence of periosteal reaction at the site (Figs. 1 and 2). No definite roentgenographic diagnosis could be offered.

The patient was studied in the Hospital for a period of six days. Repeated *blood and urine* examinations were within normal limits. The blood serology was negative. The blood sedimentation rate was 6.0 millimeters per hour. Blood chemistry values on the day of admission (April 7) were:

Blood calcium *	13.2 milligrams per 100 cubic centimeters
Alkaline phosphatase	11.4 Bodansky units per 100 cubic centimeters
Serum inorganic phosphorus	6.6 milligrams per 100 cubic centimeters

Repeat tests five days later (April 12) showed:

Blood calcium	11.15 milligrams per 100 cubic centimeters
Alkaline phosphatase	*13.9 Bodansky units per 100 cubic centimeters*
Serum inorganic phosphorus	*7.1 milligrams per 100 cubic centimeters*

Roentgenograms of the skull, femur, and chest were negative.

At operation the periosteum appeared to be everywhere intact, and unthickened. A small area of *bluish discoloration* was seen in the *periosteum.* The *bone beneath this spot of discoloration felt soft,* as though there were a defect in the continuity of the cortex. The periosteum was then split, and the area of the lesion in the underlying cortex was exposed. The involved area appeared to be gelatinous, and measured about 1.5 centimeters in diameter. This area of soft gelatinous tissue was situated within the cortex, and had replaced the bone. The overlying periosteum and the entire section of involved tibia were removed.

Postoperative convalescence was uneventful. Roentgenograms taken after the operation showed a complete excision of the bone lesion (Fig. 3).

Since his discharge from the Hospital, the patient has been seen regularly in the Orthopaedic Clinic. He has been entirely free of symptoms. *Blood studies made on the day of his discharge from the Hospital* showed:

Serum inorganic phosphorus	4.8 milligrams per 100 cubic centimeters
Alkaline phosphatase	2.8 Bodansky units per 100 cubic centimeters
Acid phosphatase	3.0 King-Armstrong units per 100 cubic centimeters

* This lone value for blood serum calcium was not confirmed; all other values listed, however, were confirmed by duplicate and triplicate determinations.

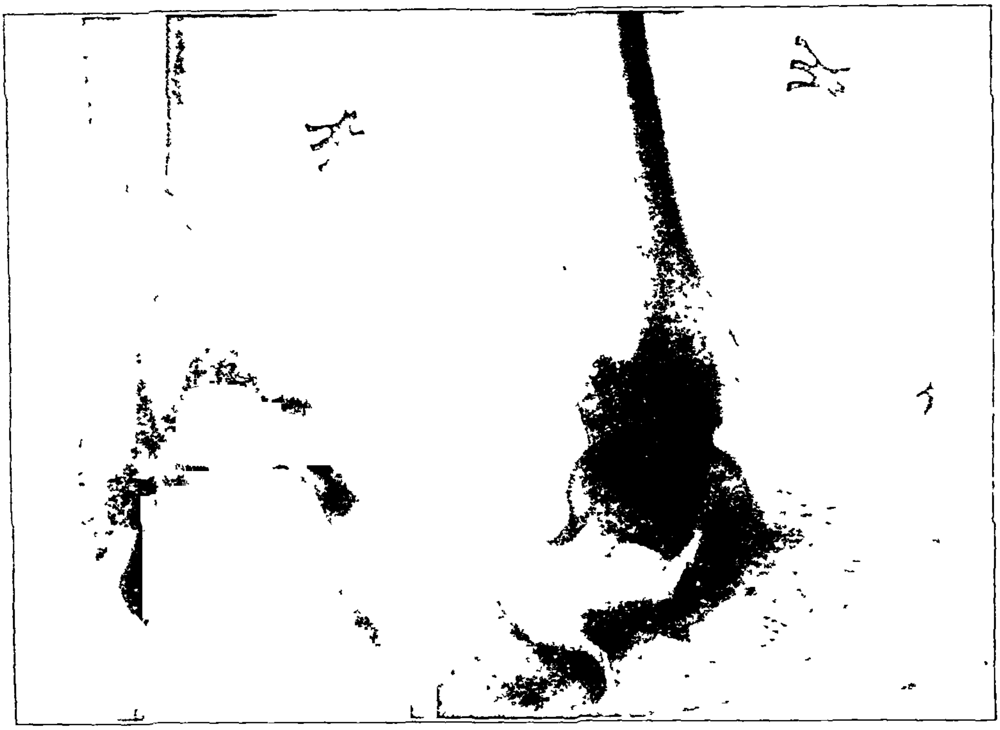

FIG. 3
Roentgenograms taken immediately after the operation to show the excision of the original lesion in its entirety, leaving a defect at the site of the tumor. The adjacent bone appears normal, and the margins of the operative defect are clear-cut and sharp

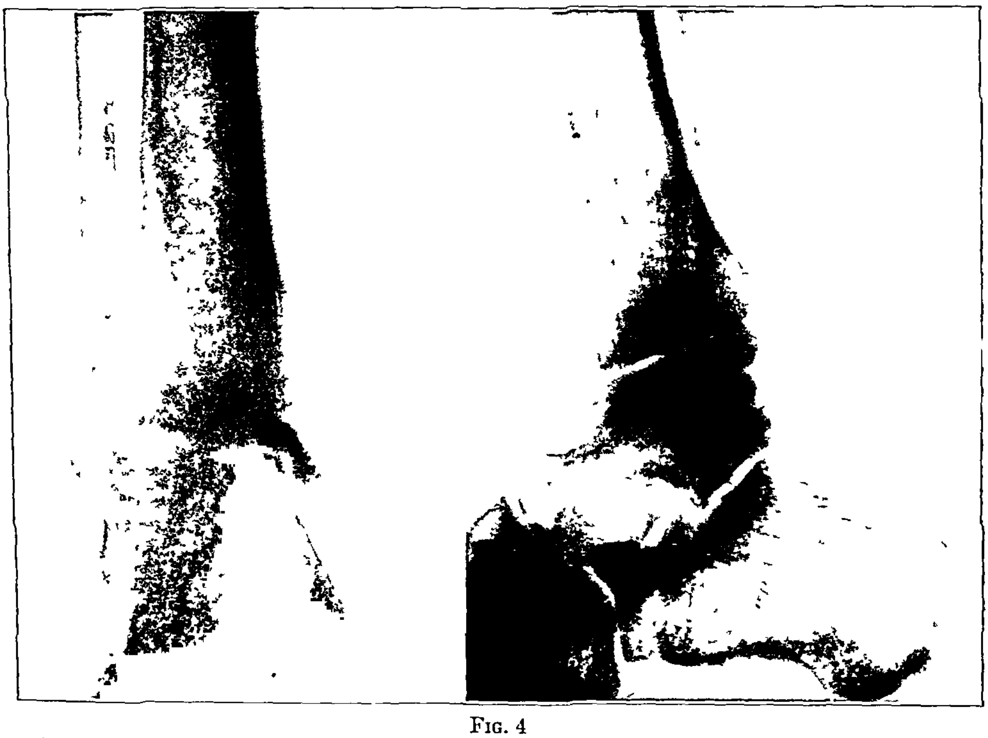

FIG. 4
Roentgenograms taken four months after the operation, showing a filling-in of the postoperative defect with the return of the bone to normal.

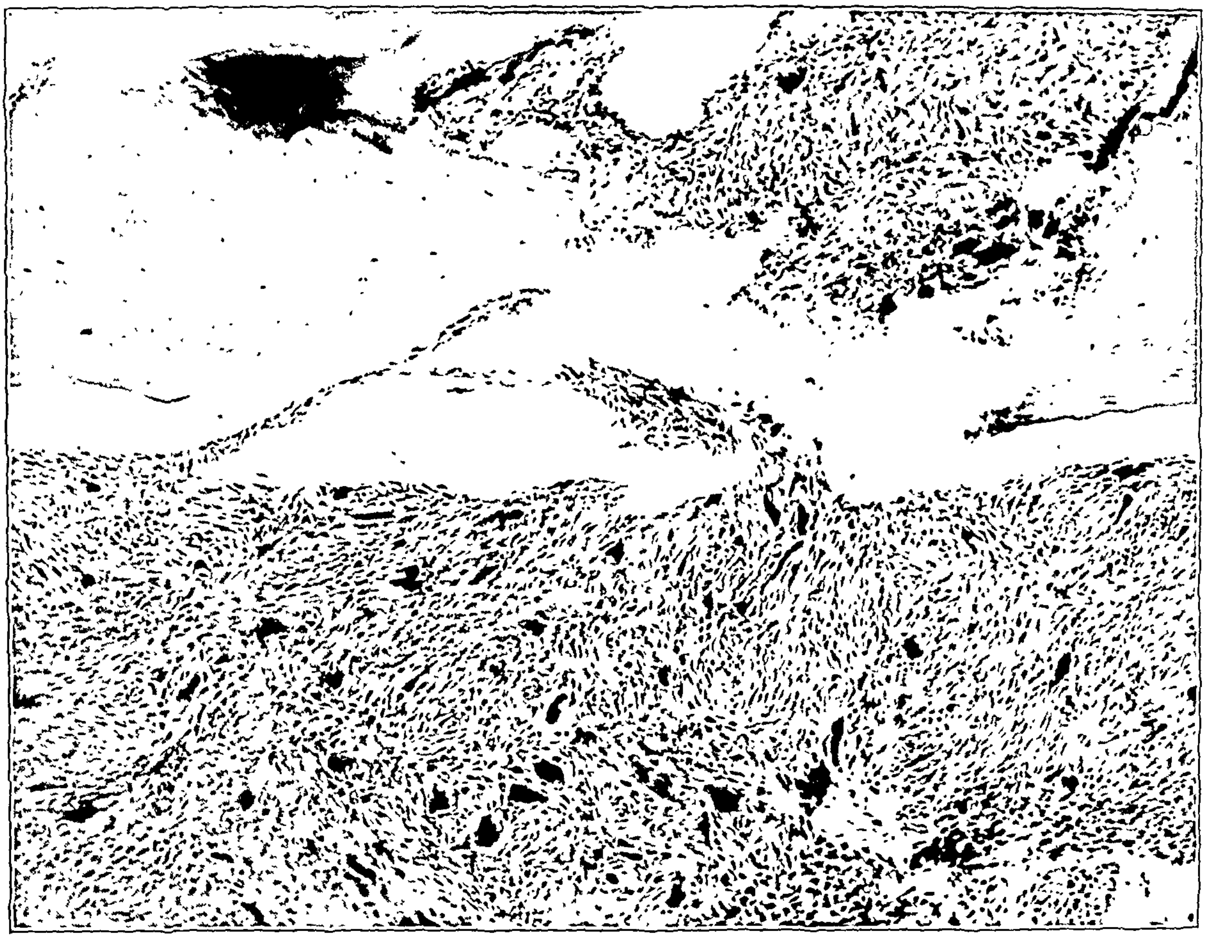

FIG. 5

Photomicrograph (× 100) showing the nature of the cortical lesion and its encroachment upon and dissolution of the bone. The pattern of the fibrous stroma and the relationship of stroma and giant cells stand out clearly (stained with eosin methylene blue).

Roentgenographic examination of the site of the tumor four months after operation (August 9) showed a return of the bone to normal, with a healing of the operative defect (Fig. 4).

PATHOLOGY

The gross specimen consisted of a single wedge-shaped piece of cortical bone measuring 1.5 by 1.0 by 0.8 centimeters. The central portion of the specimen showed an irregular defect in the outer surface of the cortex. This defect was due to the replacement of the bone by soft, pinkish-gray, friable tissue, which lay within the substance of the cortex. The entire area occupied by this tissue measured less than 1.0 by 0.6 by 0.6 centimeters. The specimen was fixed in Zenker's solution for histological study.

Sections (Figs. 5, 6, 7, and 8) show a tumor-like growth, composed chiefly of fibrous tissue and giant cells, replacing cortical bone. The growth extends from beneath the periosteum through the greater part of the thickness of the cortex, but it does not encroach upon the medullary cavity. This fibrous tissue is composed chiefly of irregular bundles of spindle cells, resembling fibroblasts. These cells and their nuclei vary in size. The nuclei are oval, clear, and vesicular, and show small but prominent fragments of nucleolar chromatin. Some intercellular collagen is seen, but this is sparse. Mitotic figures are scarce. Scattered among the spindle-shaped stroma cells are numerous multinucleated giant cells of the foreign-body type. The giant cells vary in size, shape, and in the number of nuclei. As many as ten nuclei are seen in the larger cells. The distribution of these giant cells is not uniform, and in places they tend to form small clusters. Fresh hemorrhage is scattered throughout this lesion, and in addition a moderate amount of golden-yellow hemosiderin is found, lying free in the tissue as well as within the stroma cells and other phagocytes. Although there is no definite association of the giant cells with the hemorrhage, they tend to clump most prominently in the regions of greatest bleeding. Foam cells are absent.

There is no evidence of formation of new bone, nor is there any evidence of acute inflammation, or of necrosis of bone.

On the basis of the gross and histological features of this lesion, it is felt that the tumor-like growth in bone represents a response to trauma, which occurred approximately six months before examination. This unusual reparative response of subperiosteal bone to injury resembles in its growth a benign giant-cell tumor. There is no evidence of malignancy.

DISCUSSION

Possibly the most striking feature of this case is the limitation of the destructive lesion to the cortex of the bone. This is a very unusual location for a benign tumor-like growth. Cortical lesions arising in the cortex are almost invariably inflammatory in nature or frankly malignant. The less virulent inflammations of bone, including chronic localized pyogenic osteomyelitis, syphilis, and tuberculosis, however, do not as a rule conform to the features of the lesion in this case; nor is the picture consistent with osteogenic sarcoma.

Destruction of the bony cortex has been described several times in association with generalized von Recklinghausen's neurofibromatosis[1,5,8,9], or even in association with a localized nerve-sheath tumor, a neurilemmoma[3]. Such disease processes, when seen in the cortex, usually start with an involvement of the periosteal nerves, and lead to a gradual excavation of the bone by the invading tumor. These nerve tumors, however, show their own characteristic histological patterns which are quite different from that of the giant-cell lesion herein described.

Individual osseous lesions of neurofibromatosis may bear a striking roentgenographic similarity to the traumatic lesion here described, even though the lesions vary so considerably histologically. This is well illustrated in a case recently reported by Green and Rudo, wherein a rounded defect was found in the tibia, which was involved by neurofibromatosis. The authors rightfully interpreted this defect as the first step in the development of a neurofibroma within the bone. The roentgenogram of this neurofibromatous lesion, as it appeared in the publication of Green and Rudo, bears a striking similarity to the lesion under discussion, and serves to emphasize that the two processes cannot be completely

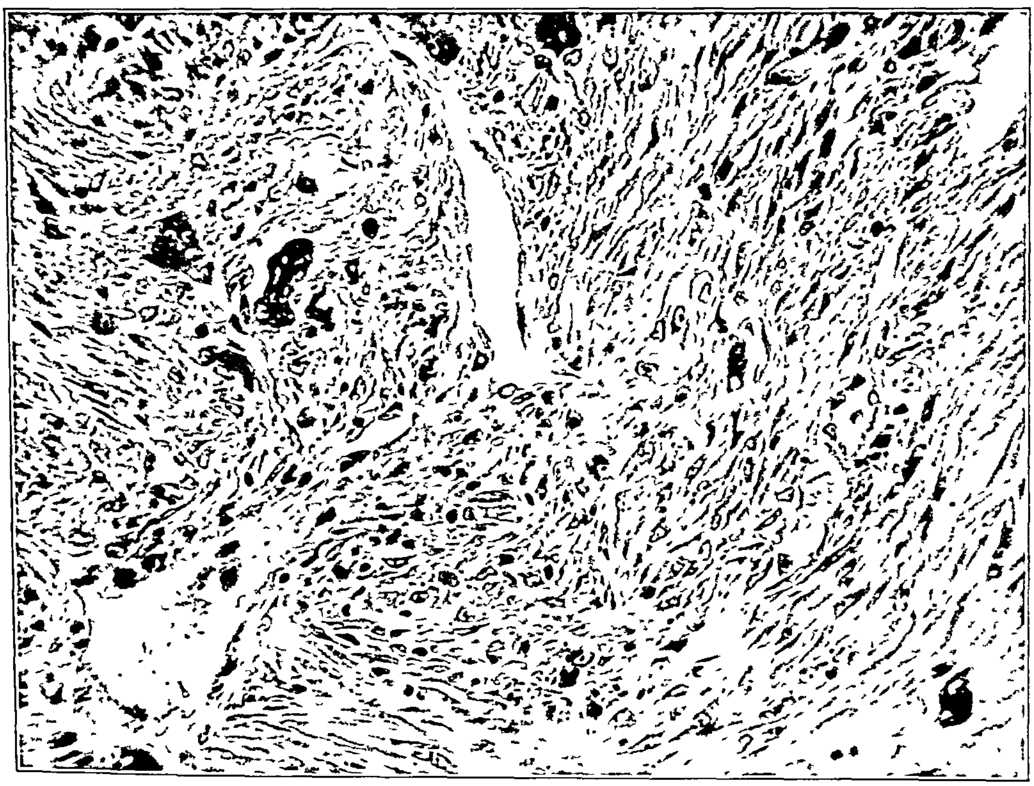

FIG. 6

Photomicrograph (× 380). The lesion was moderately vascular, being supplied by irregular blood channels formed by the peculiar stromal fibrous tissue In almost every field there could be seen, under the microscope, fresh hemorrhage and old blood pigment There was no evidence of new-bone formation

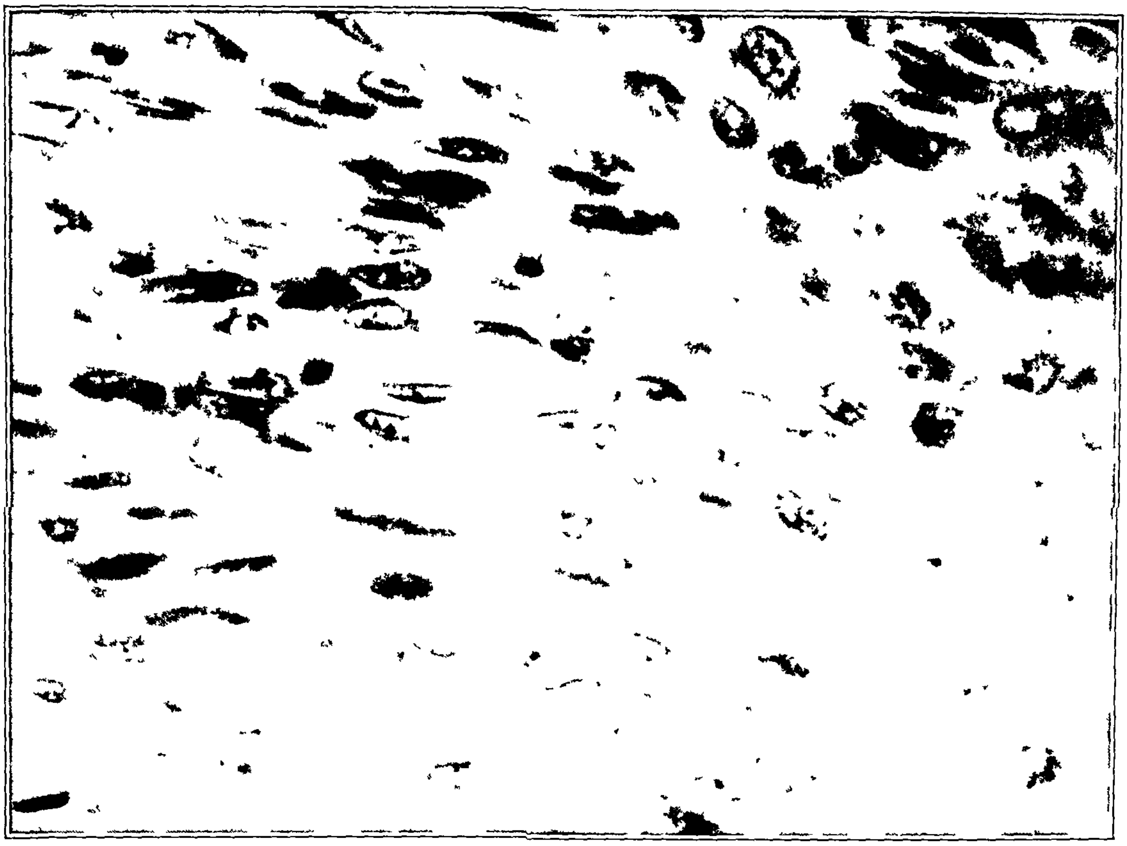

FIG 7

Photomiciograph (× 640). The stiomal-cell nuclei aie oval to iound, vesicular, and contain piominent nucleolai fiagments Theii cell outlines aie not always distinct, and the amount of intei cellulai collagen is vaiiable, but nevei abundant.

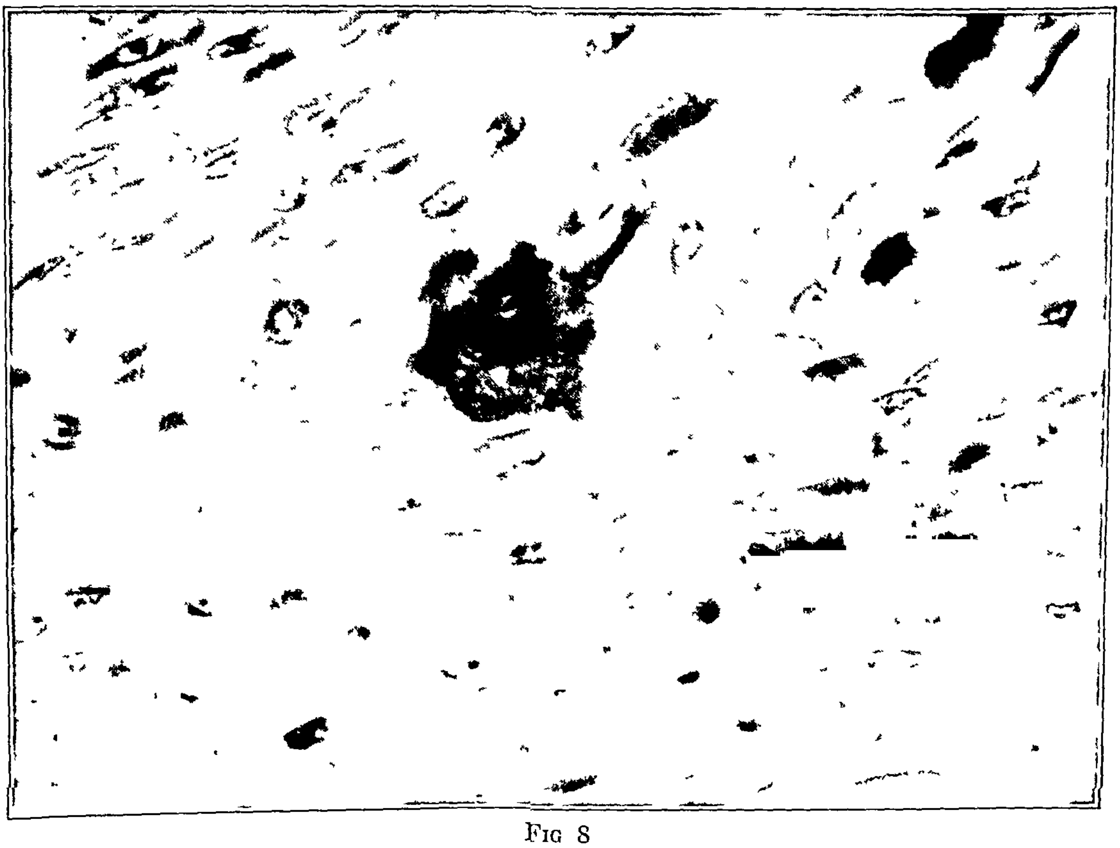

FIG 8

Photomiciogiaph (× 640). The association of giant cells and stioma is intimate The nuclei of the giant cells iesemble closely those of the stromal cells Rare mitoses aie seen in the stioma.

differentiated by the roentgenograms alone. Such are the common lesions of bone associated primarily with subperiosteal cortical destruction.

As an expanding medullary lesion, the giant-cell tumor of bone is readily identified, and would probably occasion no confusion roentgenographically with a lesion such as we have described here. However, more recently it has been shown that an essentially similar lesion can arise within the cortex beneath the periosteum. Geschickter and Copeland have accumulated four such cases. They included also the lesion described by Cone under the heading of "ossifying hematoma". These subperiosteal benign giant-cell lesions in all instances followed trauma to the bone with hemorrhage and separation of the periosteum.

Certainly the close association of Geschickter's subperiosteal giant-cell tumors with trauma, the location of the lesion within the cortex, and the dissolution of the cortical bone are suggestive of the case herein described. The association of giant cells with fibrous tissue is also consistent. However, the similarity between these two lesions cannot be followed completely. In the case described herein, removal of the periosteum revealed no "shell of bone", and upon incision there was no "cavity containing blood". True, there was evidence of old and fresh hemorrhage in the lesion, and certainly this hemorrhage is significant, but probably does not warrant the conclusion that hemorrhage and disturbance of the periosteal blood supply is the primary cause of the lesion, as Geschickter believes to be the case with giant-cell tumors.

Although Geschickter and Copeland made no mention of new-bone formation in their four cases of subperiosteal giant-cell tumor, they included Cone's case of ossifying hematoma as a typical example of the lesions they were discussing. An outstanding feature of Cone's "ossifying hematoma" was the formation of new bone within the zones of organizing hemorrhage. In the case under discussion, new-bone formation is conspicuous by its absence.

The absence of new-bone formation is the second outstanding feature of this cortical bone lesion. Jaffe and Lichtenstein have described a benign tumor of bone characterized by the lack of bone formation under the heading of "non-osteogenic fibroma of bone". Clinically most of the patients with non-osteogenic fibromata, while giving no history of trauma, had pain or swelling of long duration about a joint. The usual site for this lesion was the shaft of a long tubular bone, usually of the lower extremity. Again the lesion was not a cortical one, but rather began in the medulla. The authors remarked that, "the lesion may show up roentgenographically as a sharply delimited, eccentric, somewhat loculated area of rarefaction traversing the bone and even bulging it out on both sides". Pathologically the lesion of non-osteogenic fibroma was described as "consisting grossly of several discrete but contiguous yellow-brown fibrous foci whose basic microscopic pattern was found to be made up of whorled bundles of spindle-shaped connective-tissue cells, loosely interspersed with small multinuclear giant cells, though, in some lesions, areas containing foam cells may also be present and even prominent".

Upon comparing the lesion under discussion with the non-osteogenic fibroma of Jaffe and Lichtenstein, one is struck by the similarity of the histological patterns, and the dissimilarity in the locations of the lesions.

The possibility that this lesion might be a variant of osteitis fibrosa or of fibrous displasia[8] is also remote, for both of these processes are primarily medullary lesions, and are capable of producing bone.

SUMMARY

An unusual destructive lesion of bone was first examined six months following trauma to the tibia; it was limited to the cortex of the bone, and showed no periosteal or medullary involvement. Histologically the cortical bone was replaced by fibrous tissue and giant cells. There was associated old and fresh hemorrhage, but there was no evidence of new-bone formation.

This lesion does not fall within any definitely known category of bone pathology. It

is best considered as a benign lesion which represents an unusual reparative response on the part of the bone to injury.

NOTE: The authors wish to extend their deepest gratitude to H. E. MacMahon, M.D., Henry Jaffe, M.D., Joseph L'Episcopo, M.D., and Jean Oliver, M.D., for their help with the histological interpretation of this lesion, and to Herman Osgood, M.D., for his assistance with the roentgenographic studies.

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SAGITTAL CLEFT (BUTTERFLY) VERTEBRA

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One hundred years ago von Rokitansky described a congenital division of the twelfth thoracic vertebral body into two lateral halves with an intervening sagittal cleft. Since then, the literature dealing with this condition has not been abundant, particularly in English. The majority of reported cases have been in the form of single case reports from European clinics. In some of these cases, the anomaly has been reported as a cause of symptoms in the back, although in others there have been no symptoms. In a given case, the clinical evaluation of this anomaly may present certain difficulties. The following cases illustrate several of the typical features of the condition.

CASE REPORTS

CASE 1. A private, aged thirty-eight, was admitted to Bruns General Hospital on December 31, 1943. Six days before he had been struck by an automobile, and a plaster-of-Paris body jacket had been applied at another hospital. The patient stated that for five years he had suffered low-back pain, which was located in the mid-lumbar region. The pain had never been severe, and the patient had never consulted a doctor. He had been able to perform his civilian duties as a car painter without difficulty. However, with the increased activity of Army life, he had noticed increased pain in the affected area. Roentgenograms revealed an unusual vertebral anomaly: the body of the third lumbar vertebra was divided into two somewhat unequal halves (Fig. 1-A); the left half was slightly larger than the right, producing a mild left lumbar scoliosis. An indentation was present on the right side of the third lumbar vertebral body, but absent on the left. Very slight narrowing of the adjacent intervertebral spaces was noted. The lateral view (Fig. 1-B) showed anterior wedging of the halves of the third lumbar vertebra with possible slight compensatory enlargement of the anterior portion of the fourth lumbar vertebra. A small hypertrophic spur was seen at the anteroposterior margin of the fifth lumbar vertebral body. The right and left oblique views (Figs. 1-C and 1-D) showed a slight relative narrowing of the joint spaces between the adjacent articular facets of the second and third lumbar vertebrae. The neural arches were intact, and showed no evidence of defect.

Clinically, examination of the spine was not remarkable, except for some loss of the normal lumbar curve, tenderness to percussion over the mid-lumbar spine, and a slight left lumbar scoliosis on extreme flexion of the spine.

The patient soon lost his lumbar pain, and was released from the hospital after full recovery from a simple fracture of the left fibula, suffered at the time of the accident. He was assigned to duties which did not involve heavy lifting, prolonged walking, standing, and drilling.

CASE 2. A corporal, aged twenty-three, was seen in the Orthopaedic Clinic at Bruns General Hospital on July 19, 1944. His chief complaint was thoracic and lumbar backache, which occurred upon heavy lifting, as well as during prolonged hiking with a pack. This pain first occurred when the patient was sixteen, and at that time it was noticed that his back was rounded. In civilian life, the patient had given up a position as a waiter because of the back pain, which occurred while he was carrying heavy trays of silverware. Since entering the Army, the patient's duties had necessarily been limited because of this disability.

Clinical examination showed a marked kyphosis at the level of the tip of the seventh thoracic spinous process. The kyphosis was fixed, resulting in some limitation of motion in the thoracic spine. A compensatory increase of the normal lumbar curve was present.

Lateral roentgenogram (Fig. 2-A) revealed an absence of the anterior third of the eighth thoracic vertebra, with marked wedging of the remaining portion of the vertebral body. The anterosuperior margin of this vertebra produced an indentation in the inferior surface of the seventh thoracic vertebra. Slight irregularities in the end surfaces of the adjacent vertebrae were noted. The anteroposterior view (Fig. 2-B) showed, in addition to the previously described eighth thoracic vertebra, a division of the seventh thoracic vertebra into two halves by means of an irregular narrow cleft. There was no anterior wedging or lateral displacement of the two halves of the seventh thoracic vertebral body.

It was recommended that the patient be assigned to light duties which would not place an undue strain on his back.

FIG. 1-A

Case 1. Roentgenogram showing the body of the third lumbar vertebra divided into two unequal halves.

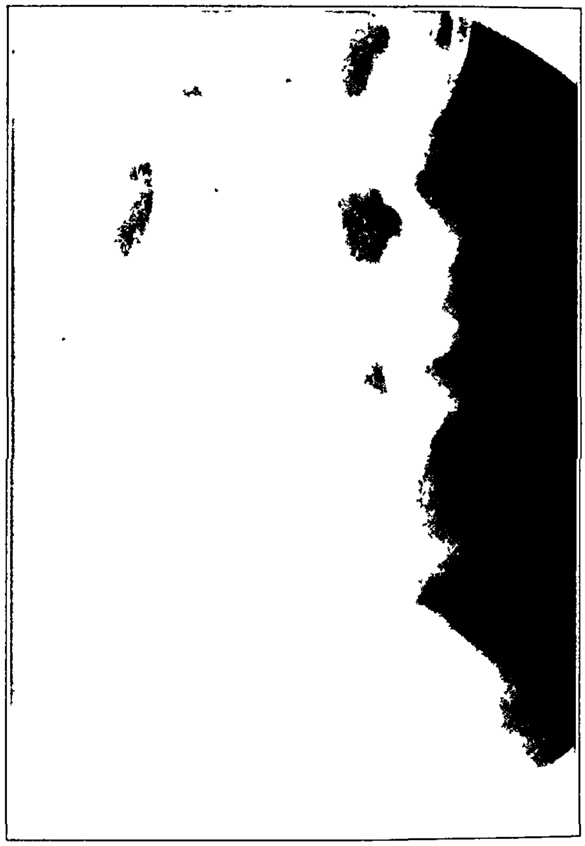

FIG. 1-B

Lateral view. The wedging anteriorly of the third lumbar vertebra simulates a compression fracture.

FIG. 1-C

Right oblique view.

FIG. 1-D

Left oblique view.

FIG. 2-A
Case 2. Lateral roentgenogram showing absence of the anterior third of the eighth thoracic vertebra with wedging of the remaining portion of the vertebral body.

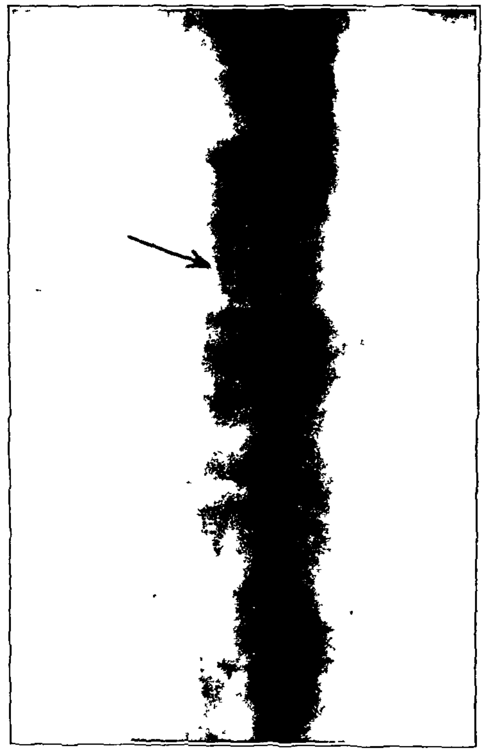

FIG. 2-B
Anteroposterior view. A narrow irregular cleft separates the seventh thoracic vertebra into two halves.

In this case, the cleft seventh thoracic vertebra was not compressed anteriorly, nor were the lateral masses displaced, so there is no evidence to suggest that the cleft vertebra caused the symptoms. In contrast, the grossly malformed eighth thoracic vertebra produced a severe kyphosis and a secondary lumbar lordosis. Sagittal cleft vertebra may be associated with other malformations of the vertebrae and the ribs.

ROENTGENOGRAPHIC FINDINGS

The typical "butterfly" appearance is seen on the anteroposterior view, where the wings of the butterfly are represented by the two symmetrical halves of the vertebral body. The two halves may be separated by a wide cleft, bridged by strands of bone, a bony bridge, or demarcated only by a narrow sagittal cleft between the two halves (Fig. 3 *A*, *B*, *C*, *D*). In this typical picture, the halves are of equal size; however, they may be slightly unequal, displaced laterally or wedged anteriorly. Resultant scoliosis or kyphosis may be noted. The adjacent intervertebral spaces may be narrowed, but not collapsed. Compensatory changes may occur in the adjacent vertebrae, as if an attempt had been made to fill in the deficiencies in the form of the anomalous vertebra. Other vertebral and rib anomalies may be associated.

TREATMENT

Treatment is not indicated in asymptomatic cases, and in cases with only mild deformity. In the usual case, correction of the kyphosis or scoliosis is not practical. Limitation of activity and the avoidance of heavy lifting will result in relief of pain in certain cases. Pain is also relieved by the use of an external support; internal fixation by means of a bone-graft has apparently seldom been warranted up to the present decade.

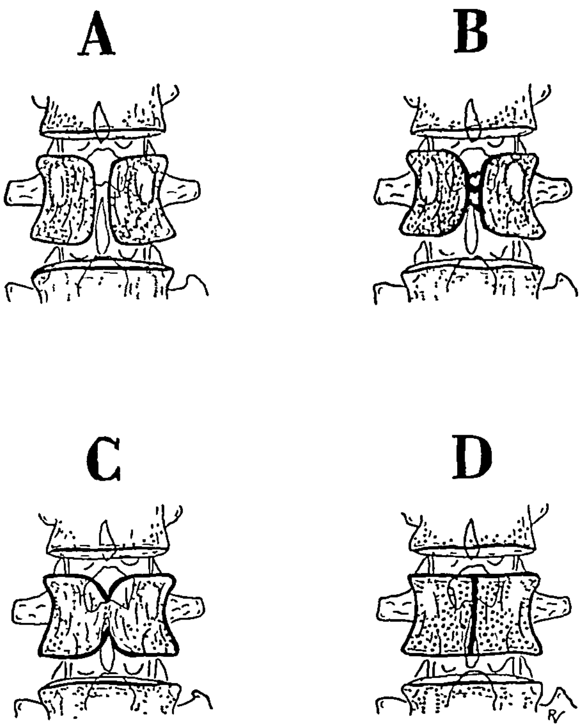

FIG. 3

Variations in the sagittal cleft which may be *A*: wide, *B*: bridged by small bony strands, *C*: crossed by a bony bridge, or *D*: narrow. Further variations in the butterfly appearance result from inequality of the vertebral halves or their lateral displacement.

CONCLUSIONS

The reported cases of sagittal cleft vertebra are too few to permit a final clinical evaluation of the condition. It is evident, however, that from an orthopaedic standpoint, the cases fall into two principal groups, the symptomatic and the asymptomatic. The symptomatic group are usually characterized clinically by the presence of mild, moderate, or severe local deformity occasionally followed by pain, and roentgenographically by anterior compression of the vertebral body halves, and less frequently, by inequality of the two vertebral halves or their lateral displacement. In these cases, the sagittal cleft roentgenographically distinguishes the anomaly from unreduced vertebral body fractures with anterior or lateral compression and lateral displacement. Clinically the symptomatology may resemble that seen in old unreduced fractures of the vertebral body. Certain asymptomatic cases are characterized clinically by the absence of deformity. Roentgenographically they show division, not always complete, of the vertebral body into two equal halves, without anterior compression or lateral displacement. It seems unnecessary to discuss in detail the embryological and pathological aspects of this anomaly, which have been thoroughly reviewed so recently by Ehrenhaft.

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GUNSHOT WOUND WITH OSTEOMYELITIC DESTRUCTION OF THE BODY OF THE THIRD CERVICAL VERTEBRA

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A private was admitted to Deshon General Hospital on October 26, 1944, as an overseas casualty, having been wounded by a machine-gun bullet in France on August 28, 1944 The bullet entered the right side of his jaw, passed down through the body of the third cervical vertebra, and lodged in the soft tissue on the left side of his neck As a result of this wound, he suffered a compound fracture of the ramus of the mandible on the right, and a compound fracture of the third cervical vertebra He had received prompt medical attention at the scene of injury, and was quickly transported to an Evacuation Hospital in the Zone of Combat, where the wound over his jaw was closed, his teeth were wired, and the foreign body was removed from the left side of his neck From the Evacuation Hospital, he was taken to a General Hospital in England, where he arrived on August 31, 1944. It was not immediately apparent that he had suffered the fracture of the third cervical vertebra, but, at the General Hospital in England, the fracture was reported, and the patient was placed in a Minerva-type plaster cast in order to immobilize his neck (Fig 1). The fractured jaw was treated by wiring with elastic-band traction for immobilization His course in the General Hospital was complicated by the development of pneumonia, which readily responded to sulfadiazine therapy On October 7, 1944, he was boarded for the Zone of the Interior, and transported back to the continental limits of the United States, finally arriving at Deshon General Hospital

Upon admission, he was in fair physical condition, considering the gravity of his injuries His cast was in good condition, and his jaws were adequately immobilized with a good reduction of the mandibular fracture. Although temperature was within normal range, the patient had a hacking cough, productive of a considerable quantity of thick sputum His complaints were limited to the cough, with some pain in the chest, and to radiation of pain down the left arm whenever he coughed An offensive odor to his cast was found to result from a pressure sore, which had developed over the posterior aspect It was necessary to remove the plaster cast in order to treat the pressure sore, to get adequate views of the cervical fracture, and to examine his chest satisfactorily Roentgenograms of the cervical spine showed a destructive process present in the body of the third cervical vertebra (Fig 2) Roentgenograms of the lung fields showed either a pneumonitis or an atelectasis The temperature and white-blood-cell count remained within normal limits, although the sedimentation rate had increased, and a culture of the sputum showed pneumococci In order to immobilize the cervical spine adequately, Crutchfield tongs were introduced through the outer table of the skull on November 13, 1944, and ten pounds of traction were applied to the head

Adequate examination of the nose and throat was impossible at this time, because of stiffness of the temporomandibular joints, brought on by the prolonged wiring which the mandibular fracture had necessitated However, by November 1, the mandibular fracture was sufficiently healed to allow adequate mobilization of the joint to be started The patient was placed on a rigid regime of gum chewing, in an effort to mobilize the joint sufficiently to permit a satisfactory laryngoscopic examination During the first week of November the patient began to show evidence of sepsis, as seen in the increased white-blood-cell count and a rising fever, which at one time rose to 104 degrees and was accompanied by a chill Along with these signs of acute infection, the patient began to complain of increasing numbness and weakness in the upper extremities By the middle of November, the neurological findings had progressed to the point where the patient showed marked motor weakness of both arms, hyperaesthesia of the arms and thorax, and questionable pyramidal-tract signs in the legs It was at this time that a sufficiently satisfactory laryngoscopic examination was possible, and a marked swelling of the posterior pharynx was seen, the tissues showed a moderate diffuse reddening Repeated cervical roentgenograms also showed a retropharyngeal swelling consistent with the laryngoscopic findings, in addition to further destruction and fragmentation of the body of the third cervical vertebra A lumbar puncture showed a complete spinal-fluid block with protein of 149 milligrams per 100 cubic centimeters, and fourteen cells per cubic millimeter At the onset of his febrile reaction, the patient had been placed on intramuscular injections of penicillin every three hours for a daily total of 200 000 units His atelectasis had cleared up in the previous weeks, as evidenced by negative clinical findings, and the absence of roentgenographic pathological signs A diagnosis of paralysis of the spinal cord at the level of the third cervical vertebra as a result of an epidural abscess was made, and surgical interference appeared urgent Opinion was divided as to the proper surgical procedure A decompression of the cord by means of a laminectomy, an inci-

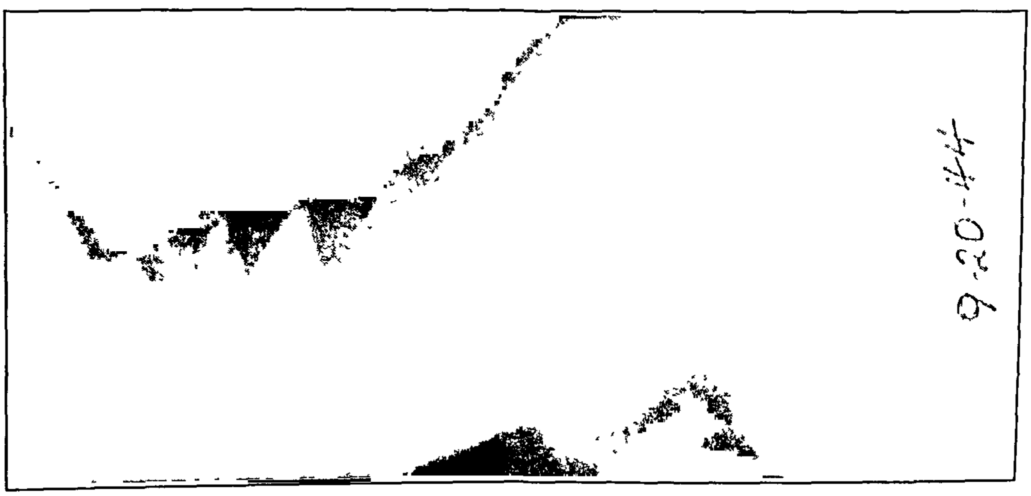

FIG. 1

Lateral roentgenogram of cervical spine taken overseas. This shows fracture of the third cervical vertebra.

FIG. 2

Lateral roentgenogram of cervical spine taken November 7, 1944, showing advanced osteomyelitic destruction of the third cervical vertebra. Note soft-tissue swelling anteriorly.

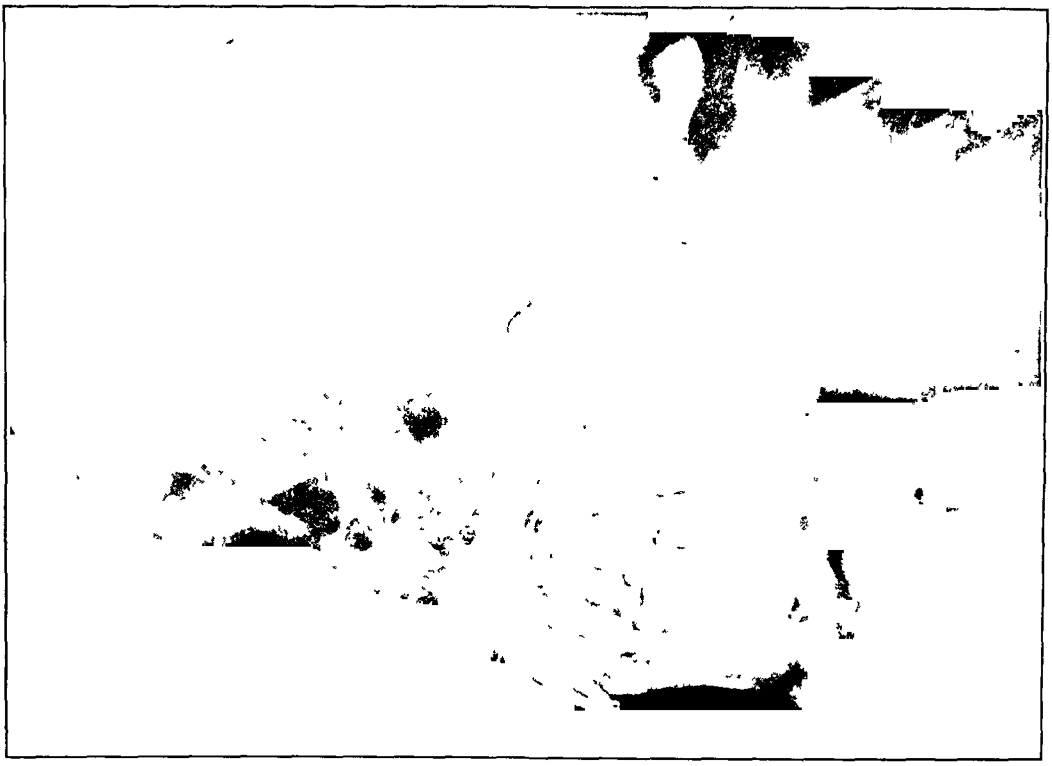

FIG. 3

Lateral view of cervical spine taken in December, following extrusion of large fragment, showing virtual disappearance of the body of the third cervical vertebra.

sion through the posterior cervical triangle for drainage of the lateral retropharyngeal space. and an incision directly into the dome of the abscess were considered. Fortunately, the abscess ruptured spontaneously into the pharynx before a decision was made. The first evidence of the spontaneous decompression was seen, when the patient coughed up several small pieces of bone. Laryngoscopic examination showed a draining fistulous opening in the posterior pharynx, just to the right of the mid-line on a level with the superior edge of the epiglottis. Suction was applied to the sinus without any great improvement in the amount of drainage obtained. The sinus continued to drain sufficiently to decompress gradually the retropharyngeal abscess, as evidenced by gradual recession in the pathological and neurological findings. On December 13, 1944, a laryngoscopic examination showed the fistulous tract to be still patent, and a grayish substance resembling a piece of bone was seen lying in the tract. It was impossible to grasp this fragment of bone with forceps, and suction was again applied to the tract in an effort to increase the amount of drainage. Apparently, as a result of the suction and the attempted extraction, the patient developed a severe coughing attack that evening, and spontaneously coughed up a fragment of bone, approximately one inch square, which resembled in structure the cortex and cancellous framework of a cervical vertebra. A considerable amount of foul-smelling pus accompanied the expectoration of this fragment of bone (Fig. 3).

From this time on, the patient showed steady improvement. The temperature returned to normal limits, the white-blood-cell count fell to a normal level, and the sedimentation rate started to drop. The neurological findings showed steady improvement: motor power increasing, hyperaesthesia receding, while the evidence of pyramidal-tract involvement disappeared. Roentgenograms of the cervical spine showed a virtually complete disappearance of the third cervical vertebra, with a regression in the previously reported retropharyngeal swelling. Lumbar punctures performed shortly thereafter revealed normal spinal-fluid dynamics with no evidence of block, normal chemistry, and a normal cell count. The fistulous tract remained patent for approximately three more weeks, although gradually diminishing in size. The amount of drainage from the tract became greatly decreased, until the sinus healed spontaneously about the middle of January 1945. With the gradual subsidence of the patient's acute infection, his general condition improved markedly. His spirits rose, and he was able to eat sufficiently to regain his strength and weight. His progress was so rapid that on February 21 his physical condition was sufficiently good to permit the formidable surgical procedure of a fusion of the second, third, and fourth cervical vertebrae.

At this time the patient showed no evidence of any neurological involvement, having regained full sensation in the upper extremities with a return to normal of his muscular strength. Prior to the operation, a plaster cast of the Minerva type was reapplied with the neck held in extension. In order to assure sufficient immobilization and traction to the neck, a walking iron was incorporated in the headpiece of the jacket, so that the Crutchfield tongs which had been applied previously could be fastened to the

FIG. 4

Side view of cast with incorporation of tongs traction to skull.

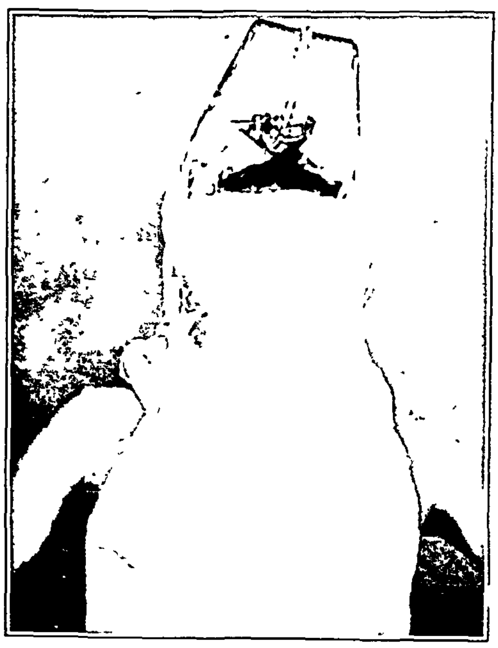

FIG. 5

Posterior view of cast with incorporation of tongs traction to skull.

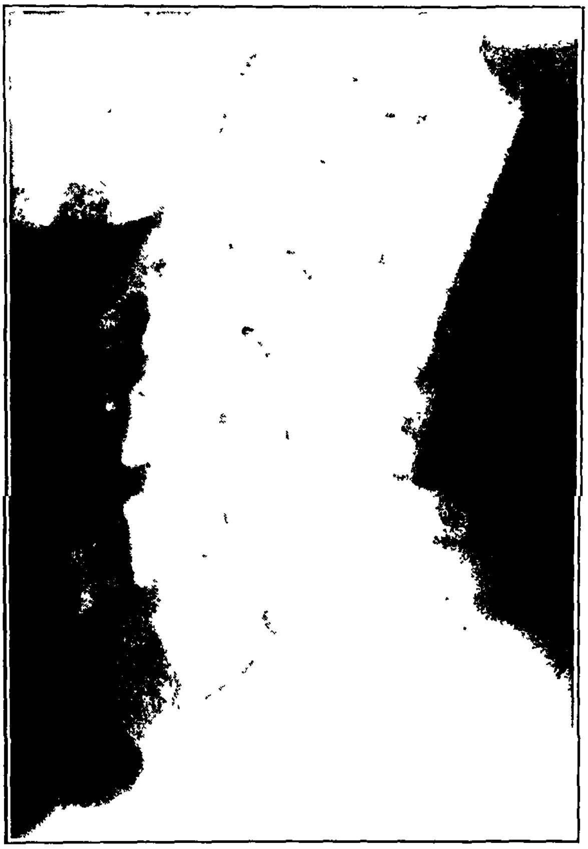

Fig. 6

Lateral view of cervical spine, taken four weeks after operation at time of plaster change and removal of Crutchfield tongs.

crosspiece of the walking iron, and thus maintain adequate traction on the neck during the cervical fusion. Adequate exposure of the operative field was obtained by removing the posterior portion of the plaster cast covering the head and neck. The walking iron with the suspension through the tongs served to immobilize the head adequately, even after this portion of the cast had been removed (Figs. 4 and 5).

The fusion of the cervical spine proved even more difficult than had been anticipated, because of the tremendous amount of bleeding encountered in an effort to expose the cervical spine. It was felt that this bleeding undoubtedly arose from the congestion due to the previous infection of the vertebral body. The bleeding was controlled with difficulty, and the *only adequate exposure of this field was obtained* when the patient went into a mild primary shock with a drop in blood pressure. Even though the blood pressure remained low, it was possible to expose completely the posterior elements of the first, second, third, fourth, and fifth cervical vertebrae, and an operation of the Albee type was performed, by raising the cortical portions of the lamina and spines of the second, third, and fourth cervical vertebrae, and inserting a three-inch tibial graft on either side of the spinous processes for fixation. In addition to the grafts, bone chips were packed between and on top of the lamina of the second, third, and fourth cervical vertebrae. It was felt that an attempt to remove the articular cartilage of the involved vertebrae in the usual fusion of the Hibbs type would be risky, because of the tremendous amount of bleeding and the shocked condition of the patient. It was possible to complete the operation only after heroic amounts of plasma had been administered. The patient received three pints of plasma and three pints of blood during the operation which lasted two and a half l ours.

The patient's postoperative course was as uneventful as his operative course was stormy. His highest postoperative temperature was 100 degrees, and, other than receiving two more transfusions for his secondary anaemia, no measures were needed beyond the usual postoperative regimen. He received penicillin intramuscularly and sulfadiazine by mouth, as prophylactics against reinfection. He was able to sit up in bed at the end of the tenth postoperative day, and was up in a wheel chair by the end of the second week. The sutures were removed at the end of four weeks, the wounds having healed *per primam,* and a new Minerva cast was applied. The Crutchfield tongs were then removed, because sufficient support was obtained by means of the plaster immobilization alone (Fig. 6).

It is, of course, too early to evaluate the ultimate result in this case. It is hoped that a good strut of bone posteriorly, running from the second to the fourth cervical vertebra, will compensate adequately for the loss of the third vertebral body. When the bone grafts have become strong enough, it is felt that all danger of a sudden flexion of the neck causing severance of the cord will be obviated. Since the first cervical vertebra was not involved in the operative procedure, the patient should obtain a fairly normal range of motion in his head and neck. It will be impossible to evaluate properly this case for at least six months or a year after the operation, and some form of external fixation will be needed during that time.

INTRA-ARTICULAR OSTEOCHONDRAL FRACTURES AS A CAUSE FOR INTERNAL DERANGEMENT OF THE KNEE IN ADOLESCENTS

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The two most common causes of internal derangements of the knee in young adults are injuries to the menisci and osteochondritis dissecans. However, injury to the meniscus is not the most common cause of knee-joint disabilities in children. The writer has seen two cases of a comparatively rare condition, that deserves more publicity, since there are undoubtedly many similar cases that go unrecognized or undiscovered until arthrotomy has been performed under the mistaken diagnosis of meniscus injury. Our cases and those already reported in the literature indicate that these intra-articular osteochondral fractures usually occur in juveniles and adolescents. It is essential that the correct diagnosis should be made at the earliest moment, so that the surgeon may perform the arthrotomy without delay, in order to prevent further damage to the cartilage and other structures within the knee joint.

Several recent reports indicate that it has been possible to make a positive diagnosis in these cases prior to operation. Milgram, in reviewing the literature on a condition which he refers to as "tangential osteochondral fracture of the patella", lists a number of reports of intra-articular osteochondral fracture of the patella. Of the cases which Milgram himself described fully, and five other cases referred to by him, most occurred in children and adolescents.

There seems to be no essential difference in the mechanism of production of the injury to the patella with subsequent formation of an osteochondral intra-articular body from that structure, and the two cases herein reported in which the osteochondral intra-articular body arose from the femoral condyles.

CASE REPORTS

CASE 1. D. H., male, aged fifteen, injured his knee while skiing, lacerating it when he fell on a stone. Physical examination showed a diagonal laceration of one and one-half inches (3.75 centimeters) over the lateral portion of the left knee joint, extending into the joint. Roentgenogram (Fig. 1) showed a small fragment of bone, lying on the lateral aspect of the lateral condyle of the femur. It was the opinion of the roentgenologist that this represented an intra-articular chip fracture.

After débridement, inspection showed that the laceration extended through the joint capsule just lateral to the patella. The fragment, which came from the marginal surface of the lateral condyle, was easily located. It was approximately three times the size anticipated from the roentgenogram (Fig. 1). The additional bulk was due to cartilage which comprised about three-fourths of the loose fragment. After removal of the fragment, the joint capsule was snugly closed with interrupted non-absorbable stitches.

The knee was aspirated on the second and third postoperative days. Bacterial cultures on both these occasions proved sterile. The patient made an uneventful recovery.

CASE 2. G. M., female, aged sixteen, was injured in a gymnasium class in February 1943. The local physician who attended the patient stated that the patella was dislocated, and there was a gross hemarthrosis, necessitating the aspiration of blood. Although the symptoms quickly became less acute, constant pain in the knee persisted, and locking occurred in flexion on six or seven occasions during the four months following the injury.

Examination of the knee, when the author first saw the patient four months after the initial injury, showed excess fluid in the joint with ballottement of the patella. Motion, both passive and active, was normal. The joint was stable. There was slight tenderness over the medial ligaments. Roentgenogram of the knee was negative (Fig. 2-A). The patient was advised to keep the knee mildly compressed with an elastic bandage, and to return at intervals for observation, as the episodes of locking made the examiner suspect a cartilage injury.

The patient was seen twice at intervals of two weeks, on both of which occasions she stated that

the pain still persisted. Tenderness could be easily elicited by pressing the patella against the femur. These further observations pointed toward chondromalacia of the patella or an internal derangement, in which either the infrapatellar fat pad or some other soft-tissue structure was interfering with adequate motion. Arthrotomy was advised. This was performed on July 23, 1943, the knee being opened through a medial parapatellar incision seven inches (17.5 centimeters) long. As soon as the joint had been opened, a large defect was seen in the articular cartilage in the medial half of the patella. This defect was irregular, and extended through the chondral portion of this bone. The defect had been filled in to some

Fig. 1

Case 1. Anteroposterior roentgenogram of knee. Arrows indicate the intra-articular osteochondral body derived from the lateral condyle of the femur.

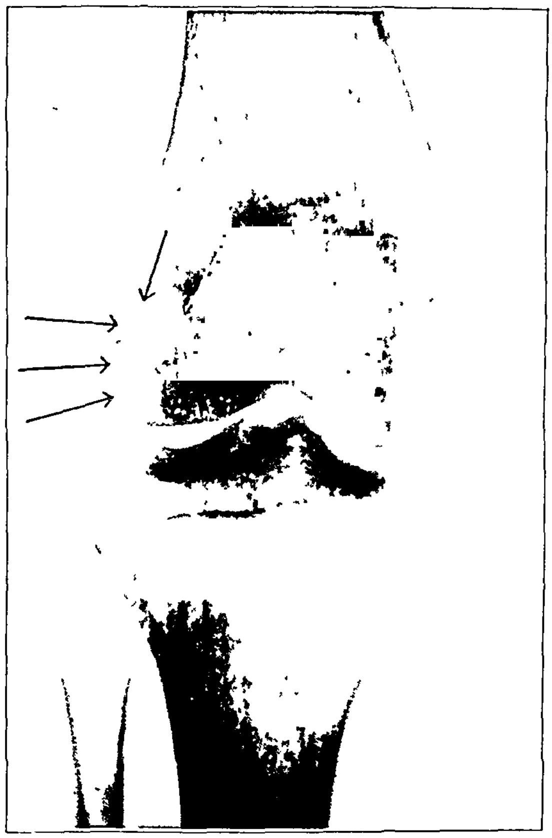

Fig. 2-A

Case 2. Anteroposterior roentgenogram of knee. The shadows of the osteochondral body are quite hazy, and they were identified only after the body was discovered at arthrotomy. The arrows indicate the position of the fragment.

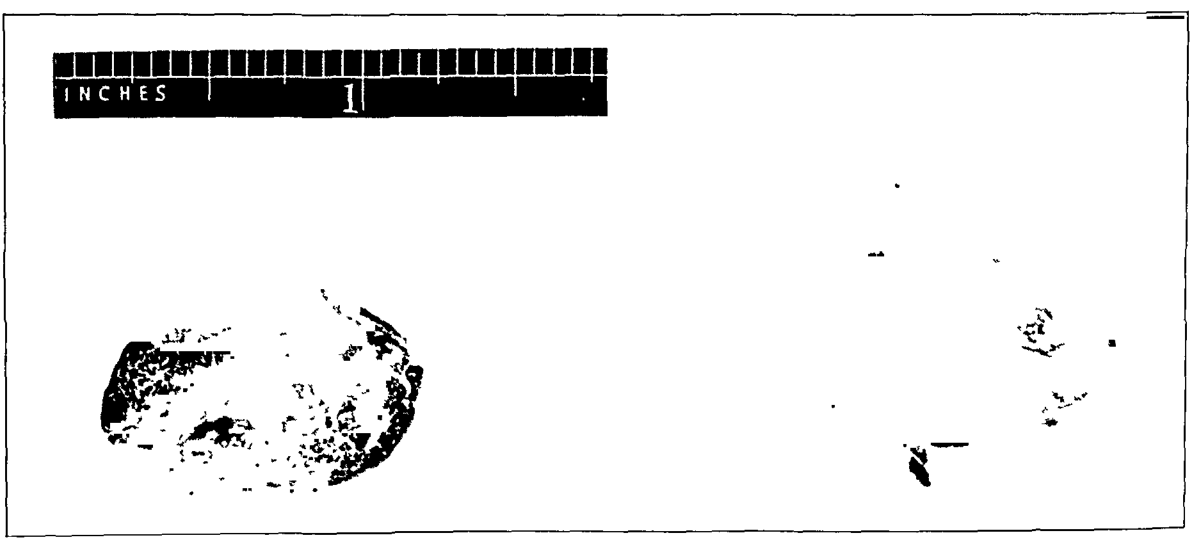

Fig. 2-B

Views of the osteochondral loose body removed from knee in Case 2. Note the roughness on the posterior surface. This appearance is undoubtedly due to the irregular deposit of fibrin and fibrocartilage on the former bare osseous surface of this fragment.

extent with fibrocartilage. There was a corresponding groove in the cartilage of the medial femoral condyle, estimated to be one-eighth of an inch (0.3 centimeter) in depth, which had been produced by the constant friction of the irregular patellar surface. Further search in the joint demonstrated a single large cartilaginous fragment at the level of the lateral femoral condyle and firmly adherent, being bound down on the lateral aspect by numerous fibrous adhesions. The body (Fig. 2-B), when removed, resembled in size the cartilage defect in the medial half of the patella. After removal of the loose body, the groove in the medial femoral condyle was made smooth by paring the rough margins with the scalpel. The knee joint was closed in layers, and a plaster cylinder was applied, extending from the ankle to the junction of the middle and upper thirds of the thigh.

Reinspection of the roentgenogram (Fig. 2-A) taken before operation showed an indefinite shadow which partially overlay the lateral femoral condyle. This shadow was unquestionably due to the few osseous elements present in the detached fragment.

The postoperative course was uneventful; the patient left the Hospital on the fourth postoperative day, walking with the aid of crutches. Three weeks after the injury and ten days after removal of the plaster cylinder, she stated that her knee joint functioned better than at any time since the injury. The patient walked with a normal gait, and joint motion was normal. She was last seen one and one-half years after operation, and complications had not arisen.

DISCUSSION

The sequence of events and the operative findings leave little doubt that the intra-articular fracture was produced by the injury. In Case 1, the osteochondral fragment recovered fitted the defect; but, in Case 2, the bed of origin had been filled to some extent with fibrous tissues. Such an injury may be either direct, as occurred in Case 1, in which a stone or other sharp object penetrated the soft structures about the knee, and, in turn, injured the intra-articular structures; or the osteochondral fragment can be loosened from the patella indirectly by the trauma which had originally dislocated this structure. Since most dislocations of the patella occur in a lateral direction, it can be assumed that the lateral femoral condyle scooped the osteochondral fragment from the medial posterior aspect of the patella. The injury in either case was sharply localized.

Milgram speculated upon the possibility of a patellar dislocation producing the fractures which he described, but a clear-cut history of this occurrence was present in but one of his cases. Dislocation of the patella was confirmed in Case 2 both by the patient and by the referring physician.

The ability of the intra-articular structures to repair the defect can only be inferred in Case 1, where operation was done a few hours after the injury. Case 2, however, demonstrated the filling in of the bed of origin to about half its extent with fibrocartilage, which had formed in the five months which elapsed between the time of the original injury and the arthrotomy.

These cases bear no relation to the condition of chondromalacia of the patella, which is evidently a degenerative phenomenon affecting that bone. The experience in both of these cases would suggest that roentgenograms taken with the technique utilized for demonstration of soft-tissue shadows would reveal osteochondral fragments with greater regularity.

These cases have both been followed for sufficient periods (five years in Case 1, and two years in Case 2) to make it unlikely that there will be any recurrent disability in either joint.

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ACUTE SPONTANEOUS ABSORPTION OF BONE

Report of a Case Involving a Clavicle and a Scapula

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Acute spontaneous absorption of bone is a rare and very striking disease. It has also been called "phantom" bone.

There have been a few case reports of acute spontaneous absorption of the metatarsals and of phantom metatarsals. Usually the metatarsal bone disappears gradually, leaving only fibrous tissue in its place.

In the literature only two reports were found, which in any way resembled the case to be reported here. The first was briefly narrated in *The Boston Medical and Surgical Journal* in July 1838, and was later quoted by Costello as "without parallel in the records of surgery". A complete history of this case was subsequently published.[1] In this early case a definite fracture of the humerus and a refracture occurred before bone absorption began. However, there was no fracture or unusual trauma in the case presented here.

The second case in the literature was one of progressive atrophy of the facial bones with complete atrophy of the mandible, reported by Thoma. However, the author felt that "the disease no doubt was initiated by dental infection", whereas in the case presented here there was no infection.

The writer has not seen a report describing this condition in the scapula or the clavicle, although a case was presented * some years ago at a meeting of the Clinical Orthopaedic Society in Cleveland, Ohio, at which the writer was present. The patient was a young woman with a phantom scapula who had been followed for five years, during which

Fig. 1

Well-developed individual. Notice depression where outer two thirds of clavicle and acromion process should have been. The scar is from a biopsy.

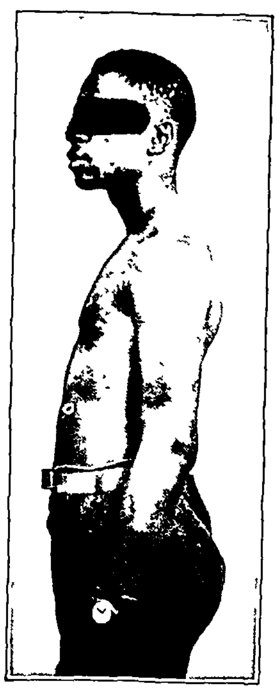

Fig. 2

Lateral view showing depression where superior border of scapula should have been.

Fig. 3

Notice loss of shoulder motion, due to absence of acromion process and clavicle.

* The name of the physician who presented the case is not recalled.

time the entire scapula had gradually disappeared. Three biopsies had been taken during this time, and the bone had been completely replaced by fibrous tissue. All laboratory tests had been consistently negative.

CASE REPORT

A twenty-year-old colored soldier entered the Hospital June 3, 1944 He was well developed and well nourished, and had no complaints other than inability to raise his left arm above his head He had had no symptoms until May 1944 when, during the ordinary duties of rifle drill at a nearby camp, he rolled over on the ground, and his rifle pressed against his left shoulder After this he had noticed some pain and discomfort in the left shoulder region Gradually he had become unable to raise his left arm above his head He entered the Camp Station Hospital on May 18, 1944, where roentgenograms of the chest and left shoulder were taken A tentative diagnosis was made of bone tumor, and he was transferred to the General Hospital on June 3, 1944 By this time his pain had disappeared, and he complained only of loss of arm motion (Fig. 3). The patient's past history and family history were entirely negative

FIG 4

Roentgenogram taken May 18, 1944. Note that inner third of left clavicle is present, but outer two thirds are gone. Notice fragments of superior border of scapula.

FIG. 5

Roentgenogram taken June 6, 1944. Note absence of clavicle, acromion process, and superior border of scapula The neck of the scapula is disappearing.

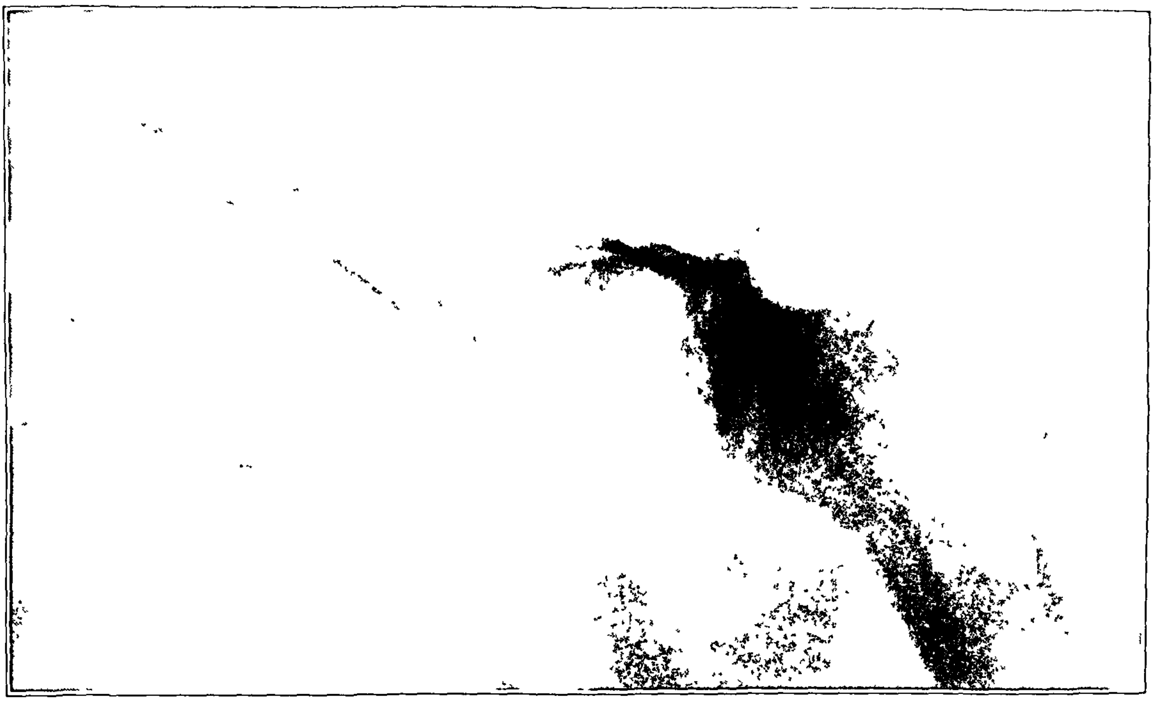

FIG. 6
Roentgenogram of left shoulder, September 11, 1944. There has been progressive absorption of clavicle, and upper portion of scapula.

In place of the left clavicle there was a depression, and mild crepitus was elicited in the upper scapular region. Arm motion was limited, but not painful. The head of the right humerus was slightly higher than the left. The rest of the examination was entirely negative.

Roentgenograms were reviewed, and revealed an absence of the outer two thirds of the left clavicle and absence of the superior border of the left scapula, involving the neck of the scapula.

Blood studies were normal, and the blood Kahn test was negative.

Red Blood Cells	4,700,000
Hemoglobin	14.2 grams per 100 cubic centimeters
White Blood Cells	6,600
Neutrophils	72 per cent.
Lymphocytes	28 per cent.
Blood calcium	9.7 milligrams per 100 cubic centimeters
Blood phosphorus	3.3 milligrams per 100 cubic centimeters
Blood phosphatase	3.7 Bodansky units

The urinalyses were normal. Roentgenographic studies of all other bones were normal. Pulmonary roentgenograms were normal, as were the gastro-intestinal studies. The kidney, urinary tract, and bladder studies were normal.

The diagnosis was phantom clavicle and scapula.

Exploration was carried out, and biopsies were taken on June 14, 1944. Grossly, only fibrous tissue was found where the clavicle should have been. and biopsy specimens under the microscope revealed only fibrous tissue. Biopsies were taken of the area of loose bone, where the superior border of the scapula should have been. Biopsy was also taken where the acromion process should have been.

PATHOLOGICAL REPORT *

"Sections taken through muscle, fat, and connective tissue [Fig. 7] show no evidence of any vascular inflammatory or neoplastic disease.

"Sections through what appeared to be the medulla of the bone showed almost complete absence of bone spicules. There are abundant remaining vascular channels from the medullary portion, and they contain red blood cells in scattered areas. Outside of these channels there is a small amount of hematopoietic tissue. There is only one area showing the presence of fibrosis. There is no evidence of an inflammatory or neoplastic process in these sections.

"Sections through actual bone [Fig. 8] show the presence of many well-formed spicules. There are definite areas of degeneration in the bone with presence of osteoclasts and localized fibrosis. At the junction of bone and cartilage, there is an irregular area of osteoid tissue as well as fibrosis.

* For this report the author is indebted to Lt. Col. Stuart W. Lippincott, Pathologist.

FIG. 7
Photomicrograph (× 16) of section through area which should have been medulla of the clavicle. (*U. S. Army Medical Museum Neg. No. 89408*)

FIG. 8
Photomicrograph (× 104) of section through actual bone of the scapula at the edge of the degenerative process. (*U. S. Army Medical Museum Neg. No. 89407*)

"The pathological changes in the bone are those of a strictly degenerative character with fibrosis. There is no evidence of an inflammatory or neoplastic lesion."

PROGRESS

After a period of six months, absorption of the clavicle, the scapula, and the neck of the scapula had progressed. The patient was without symptoms, except for loss of abduction of the arm. Pulmonary roentgenograms were normal.

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CLAVICULAR DYSOSTOSIS

A Case Report

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From a Royal Navy Hospital, Mombasa, East Africa

The clavicle, which is the first bone in the body to ossify, is occasionally the site of developmental anomalies; these maldevelopments may be associated with changes in the skull, the syndrome of hereditary cleidocranial dysostosis [2] described by Marie and Sainton in 1897. More rarely the clavicle alone is affected, although the disease may appear in one or both clavicles and take the form of underdevelopment of the central part of the collar bone, especially of the outer half.

E. D., a Second Radio Officer T124T, aged eighteen, during a routine examination was noticed to have an unduly prominent inner end to his right clavicle, with an apparent loss of bone lateral to the clavicle. Inquiry revealed that this anomaly had been present since birth, and that his sister was similarly affected. There was no other abnormality of development; and, as far as he was aware, the rest of his family was quite normal. Inspection revealed a well-developed inner half of the clavicle, which was mobile; the outer half was barely palpable, being short and rotated downward and inward. Roentgenograms showed the clavicle to be in two parts, the adjacent ends being covered with cortical bone, and having smooth, rounded contours (Figs. 1-A and 1-B). This officer suffered no inconvenience from the defect; his shoulder girdle was strong and stable, although the condition in the middle of the collar bone amounted to a pseudarthrosis. Unfortunately, it was not practicable to obtain roentgenograms of the other members of his family.

An almost identical condition has recently been recorded, affecting the right clavicle in a mother and her two daughters.[4]

FIG. 1-A

FIG. 1-B

The ossification of the clavicle has been the subject of much anatomical discussion.[1,3] Briefly it is preceded by a condensation of connective tissue in the form of a rod, in which two centers appear near the mid-point at the sixth week of intra-uterine life. Ossification proceeds from these two centers, and presumably it is the failure of these to fuse which leads to the dysostosis. A secondary center appears in cartilage at the sternal end about the twentieth year; it is extremely thin and fuses with the body at the age of twenty-five. The collar bone thus develops mainly from membranous or precartilaginous centers, and it is the association of these anomalies with those of other bones of similar origin, in the skull, which has led to the suggestion that these dystrophies are solely membranous.

NOTE: The author is indebted to the Medical Director General of the Navy, Vice-Admiral Sir Sheldon Dudley, for permission to publish this case report.

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CONGENITAL HUMERORADIAL SYNOSTOSIS

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AND

C. G. HANSON, M.D., CRANFORD, NEW JERSEY

Congenital humeroradial synostosis is an extremely rare abnormality, and the writ ers feel that the addition of this case to those already described would be of some interest Up to the present time, some twenty-four cases have been reported, nearly all of them i the European literature.

It is apparent that there is an hereditary tendency in cases of this kind, since the de formity has been reported in several siblings. Frostad reported five cases, all involvin both elbow joints; three cases occurred in one family, and two in another family. H points out what types of work these people could do in spite of the deformity. For ex ample, one was a farmer, one a tailor, and another a housemaid. These people had bee able to do their work quite satisfactorily, but they were dependent upon others for sev eral of their personal needs. The author mentions that the patients could not touch th backs of their heads, tie their neckties, button clothing over their chests, or perforn other equally difficult motions. Some patients found it awkward to feed themselves. Writ ing was difficult, because the pronated position of the hand caused the volar surface to rest on the desk. However, most of these people led useful, active lives, one being seventy-two years old at the time of Frostad's report.

Frankel reported four children in one family, who had congenital humeroradial synostosis. He feels that only an hereditary factor could cause this familial and congenital abnormality. He points out that, because of the absence of an hereditary disposition to the deformity in this particular family, a germinal change may have taken place in one of the parents, leading to the production of new characteristics. He suggests that the new characteristics may have appeared as a result of a "germinal rearrangement". A person who possesses a rare dominant condition nearly always possesses the determining gene in one chromosome only. The theory of genetics demands that half of such a person's offspring, provided he is married to a normal person, will have the dominant trait. Therefore, Frankel points out that, because of the rarity of the abnormal condition, and the absence of consanguineous marriages in this family, it is unlikely to be caused by recessive hereditary factors. It is generally assumed that if two parents are carriers, only one fourth of their offspring will show the recessive trait.

A case of a farmer, twenty-one years old, whose involvement was in one elbow only, was reported by Romanus.

Acuña and Puglisi feel that the anomaly may be due to endogenous causes.

The only reported attempt at surgery for this condition was made by Mouchet and Saint-Pierre on a boy who had a bilateral deformity. The ankylosis was sectioned, the extremities were shaped to form a joint, and a musculo-aponeurotic flap was inserted to prevent another ankylosis. Unfortunately, they do not report the results in this case, and attempts to communicate with them recently have been unsuccessful.

CASE REPORT

Mrs. C. D., white, aged twenty-four, was admitted to the Rahway Hospital on September 13, 1944, at term in her second pregnancy. She had one other child, a boy two and a half years old, living and well and showing no deformities. There had been no deformities in the family for three generations, and no consanguineous marriages. The blood Wassermann was negative, and the blood count was normal. The mother had received apparently normal dosages of a multi-vitamin preparation during the pregnancy. Her course during the pregnancy had been entirely normal, and her physical condition was

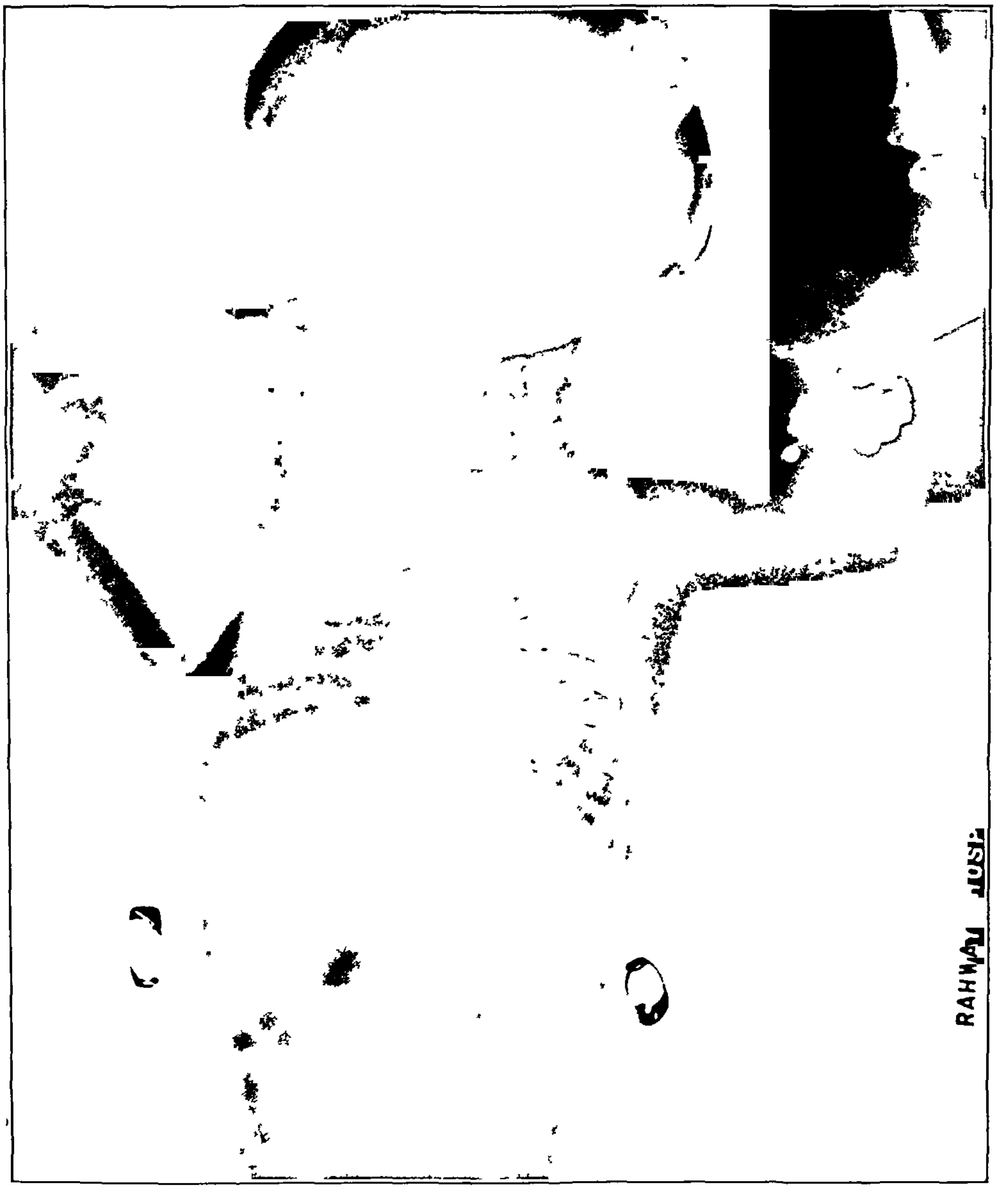

FIG 1

normal On September 14, 1944, she gave birth to a female, weighing five pounds It was soon noticed that the baby's elbows were flexed at slightly less than 90 degrees, and all attempts to straighten them were unsuccessful Roentgenograms (Fig 1) showed that there was no articulation at all at the elbow; the radius and the humerus were one continuous bone There was also some deformity of the left clavicle The child's general condition has since been entirely normal Surgery to correct the deformity has been considered, but the authors do not feel that it holds much promise

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CONGENITAL ABSENCE OF THE ODONTOID PROCESS

A Case Report

BY CAPTAIN RAYMOND C. SCANNELL

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Congenital absence of the odontoid process from the cervical axis has been reported in one case by Roberts and in two cases by Weiler. Absence of the odontoid as an attachment for ligaments and as a support for the atlas suggests the likelihood of instability in the atlanto-axial joint. All of the previously recognized cases came under observation because of dislocation of the atlas on the axis. In the author's case here presented, the patient's first symptoms were in his neck, because of an injury in which the integrity of the atlanto-axial joint was involved.

CASE REPORT

This patient, a twenty-three-year-old soldier, suffered sharp pain in the neck after a twist, sustained while wrestling on March 10, 1944. The pain was accompanied by generalized weakness, most noticeable in the arms. During the half hour following injury, the weakness gradually disappeared.

The patient received his first examination and treatment elsewhere. He reported a roentgenographic examination, application of traction for one week, and return to duty after a period of observation.

With the persistence of ill-defined complaints in the entire body, he again came under medical observation on July 5, 1944. He failed to improve, and was transferred to a General Hospital, where he first came under the writer's observation. The patient carried his head stiffly, and neck motion was limited, particularly extension. Physical findings were otherwise normal, except for a strabismus and a mild hyperhidrosis of the feet. Laboratory studies were all within normal limits. Roentgenographic studies, including laminagrams, revealed a complete absence of the odontoid process, and abnormal mobility of the atlas on the axis in flexion and extension.

FIG. 1-A

Lateral view of the cervical spine with the neck in extension.

FIG. 1-B

Lateral view of the cervical spine with the neck in flexion. Comparison with Fig. 1-A demonstrates abnormal mobility of atlas on axis

FIG. 2
No evidence of the odontoid process is noted in an open-mouth anteroposterior view. Some displacement of the first cervical vertebra on the second is present, and was noted in all anteroposterior views.

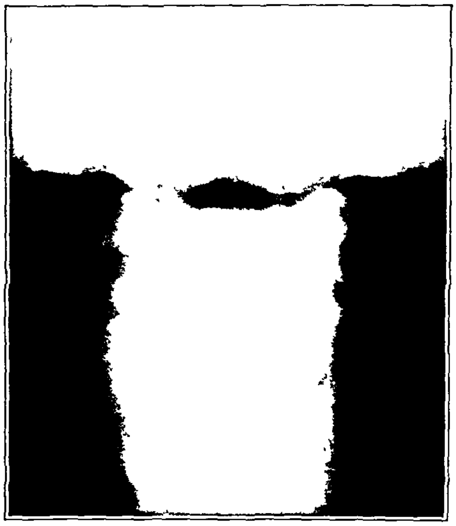

FIG. 3
Laminagraphic section through level of odontoid region.

Immobilization of the neck failed to relieve the patient's complaints. While under our observation, there was at no time objective evidence of cord damage. The soldier was considered physically unfit for further military service, and was, therefore, discharged. He desired no other treatment.

COMMENT

From a mechanical standpoint, instability of the atlas on the axis is to be expected in congenital absence of the odontoid process. This is borne out by the occurrence of atlanto-axial dislocation or subluxation in the cases of congenital absence of the odontoid, reported in the literature. Consideration of possible absence of the odontoid in diagnosis of atlanto-axial dislocation or subluxation, and a careful technique, in roentgenographic examination of upper cervical injuries, including laminagrams, are suggested. Weiler describes a fusion which he used successfully in his first case, and contemplated for his second.

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AVULSION FRACTURE OF THE ISCHIAL TUBEROSITY

A Case Report

BY CHARLES C. ABBATE, M.D., LODI, NEW JERSEY

Avulsion fracture of the ischial tuberosity may occur occasionally in individuals in whom the tuberosity has not become firmly united. In 1912, Berry [1] reported a case in England in which the fragment was removed surgically, and the condition has occasionally been reported since that time.[2,4,5,6] The patient's history usually reveals that the hamstrings, while taut, were subjected to excessive strain. The direction and the degree of displacement of the ischial tuberosity depends upon the action of the various muscles attached to the tuberosity. Thus the hamstrings pull downward, forward, and outward the adductor magnus and quadratus femoris forward, outward, and downward; while the sacrotuberous ligament, the primary antagonistic force, resists downward and outward displacement.

The following case report illustrates the manner in which fracture is produced:

The patient, at the age of sixteen, stepped on a stone while running a race, lost his balance, and fell Roentgenograms were not made, and he was treated by rest, local heat, and massage. At the time of the accident, walking produced moderately severe pain in the region of the tuberosity, radiating down the hamstrings. This pain subsided after three or four weeks, but the patient found that any excess of walking or running precipitated an episode of pain, so that he had to discontinue his track work. For six years after the original injury he had frequent bouts of pain when the related muscles were exerted. Treatment with heat and rest produced symptomatic improvement.

At the age of twenty-two, the patient sought treatment for a boring pain in the region of the left ischial tuberosity and hamstrings, which was aggravated by rising after prolonged sitting, or by sitting

Fig. 1

after he had been on his feet for any length of time. Roentgenogram (Fig. 1) showed an old avulsion fracture of the left ischial tuberosity in which there was considerable callus formation. Because of this union, and because the degree of disability was slight, conservative therapy was adhered to. Treatment consisting of rest, local heat, and the injection of procaine in oil around the callus proved adequate, although there were several recurrences of pain. The patient is now relatively free from symptoms, and occasional pain is treated with heat and rest.

Operative treatment has been recommended for this condition only if pain and disability have persisted. In such cases, the examiner may be able to elicit tenderness over the ischial tuberosity, and a poorly defined nodular mass may be felt. It then becomes necessary to extirpate the bony mass, usually by the perineal route.

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UNILATERAL CONGENITAL CALCANEOCUBOID SYNOSTOSIS WITH COMPLETE ABSENCE OF A METATARSAL AND TOE

A Case Report

BY CAPTAIN LEONARD C. VENERUSO

Medical Corps, Army of the United States

From Station Hospital, Scott Field, Illinois

Wagoner, Bargellini, and Mahaffey have reported congenital fusion of the calcaneocuboid joint, unassociated with other congenital abnormality of the bones of the foot. Holland has reported calcaneocuboid synostosis with fusion of the middle cuneiform to the second metatarsal, and of the external cuneiform to the third metatarsal. Illievitz has reported unilateral absence of one toe with talonavicular fusion. Talonavicular fusion has also been reported by Lapidus and by O'Donoghue and Sell.

CASE REPORT

A twenty-two-year-old white male was seen in the Orthopaedic Clinic of the Station Hospital, Scott Field, complaining of pain along the inner border of his right foot, aggravated by prolonged walking or

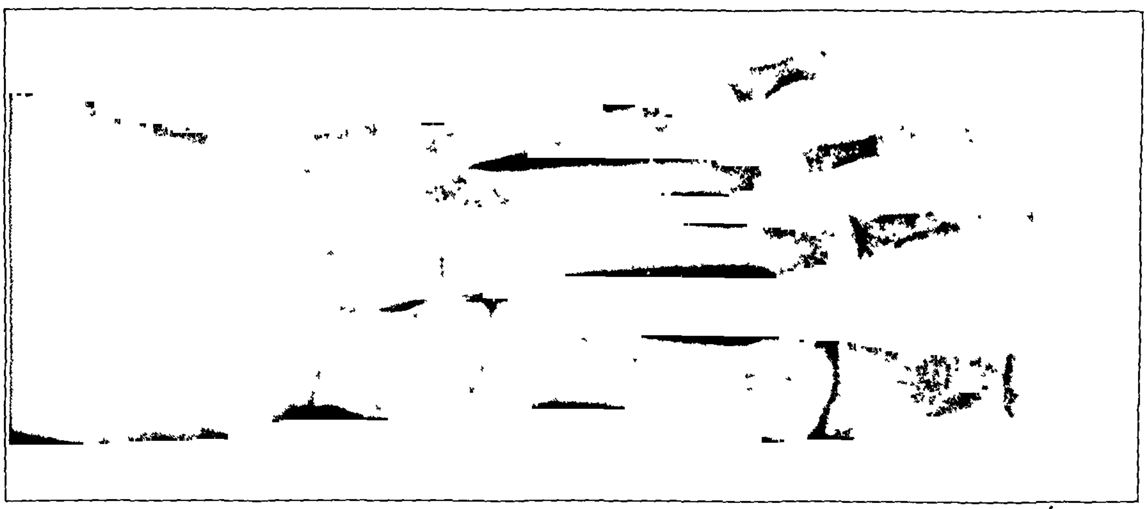

Fig. 1-A

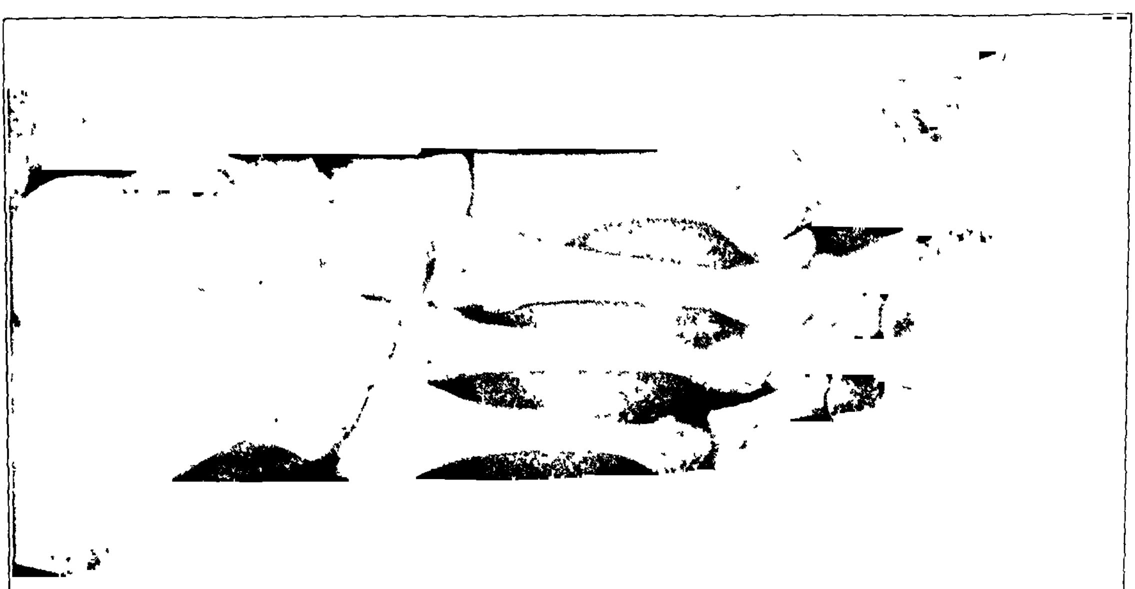

Fig. 1-B

standing. He attributed this to the fact that he was "born with only four toes on this foot". There was no history of any other member of his family having a similar condition.

At the time of examination, the patient was wearing a size 8½-D shoe on his left foot, and a size 7-D shoe on his right foot (Government-issue low-quarter shoes).

The left foot presented no abnormalities. The right foot was somewhat smaller than the left, showed a mild pes cavus, and had only four toes. The large toe on this foot was normal in size, but the other toes were larger than the corresponding toes of the left foot. Motions of the left foot were of normal range. There was slight limitation of inversion and eversion of the right foot, but the other motions were normal.

Roentgenograms were taken of both feet. The left foot showed no abnormalities. The right foot (Figs. 1-A and 1-B) revealed the complete absence of one metatarsal and its phalanges, and a fusion of the calcaneus and the cuboid bones. No evidence of a joint line between these bones could be found, and there was continuity of normal bone structure throughout.

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TRAUMATIC DEGENERATION OF THE MEDIAL HEAD OF THE GASTROCNEMIUS SIMULATING A SEMIMEMBRANOSUS BURSA

A Case Report

BY HAROLD H. COHEN, M.D., NEW YORK, N. Y.

From the Beth David Hospital, New York

The following case report is presented, both because of the rarity of the condition and the unexpected operative findings.

D. M., a man thirty-nine years old, while standing on a truck, lost his balance, and fell heavily upon the posterior aspect of the extended left knee. He arose unassisted, and continued work despite the immediate onset of pain. This accident occurred on May 23, 1944, and the patient did not seek medical attention until June 15, applying home remedies during the interval. On June 15 physical therapy was begun. He was first seen by the writer on July 18, and he complained at that time of pain in the back of the left knee, especially upon bearing weight, and toward the end of a day's work. There was frequent buckling of the knee, especially upon rising from the seated position.

FIG. 1

Photograph of specimen removed from medial head of gastrocnemius. This measured 6 by 3.5 centimeters, was grayish-yellow in color, and rather firm in consistency.

The patient's past history was irrelevant. Physical examination revealed a muscular, well nourished, adult male, five feet six and a half inches tall, and weighing 155 pounds. He walked with a slight left-leg limp, with the aid of an elastic knee support. There were moderate varicose veins over both legs. The anterior aspect of the left knee presented normal markings, with no evidence of synovial effusion or thickening. There was no atrophy of the quadriceps. The popliteal space revealed a globular swelling, cystic in character, measuring four by four centimeters, and overlying the semimembranosus muscle. This "tumor" was most clearly visualized in the erect or prone position with the knee in complete extension. When the knee was flexed, the mass became smaller, but was still palpable, and did not empty into the knee joint. The skin overlying the swelling was freely movable, while the mass itself was not attached to the underlying tissues. The mass was tender to the touch. There were no other points of tenderness. Stability of the knee was not impaired, either in the anteroposterior or the lateral direction. Motion was only slightly restricted in flexion, while extension was complete. There was no palpable enlargement of the inguinal glands. The peripheral circulation of the limb was intact, and no bruit was discernible. Roentgenographic examination of the knee joint failed to reveal evidence of an osseous lesion. A diagnosis of a semimembranosus bursa was made, and excision was advised.

The patient was again seen on August 23, when essentially the same findings were noted. Operation was again advised, and was finally carried out on October 10.

OPERATIVE TECHNIQUE

Through a slightly curved six-inch (15-centimeter) incision over the cystic swelling, the superficial and deep fascia were incised. The semimembranosus muscle and the semitendinosus tendon readily came

FIG. 2
Photomicrograph (low-power view) of section of specimen, illustrating extensive fatty-tissue replacement of striated muscle fibers

FIG 3
Photomicrograph (high-power view) of extreme left corner of Fig 2, illustrating muscle degeneration and atrophy with fatty-tissue replacement.

into view. On retraction of the semimembranosus, a large globular swelling, about the size of a small orange, and involving the medial gastrocnemius, was noted. The neurovascular bundle was pushed laterally, resting over the lateral gastrocnemius. A longitudinal tear was found, extending through the fibro tendinous margin of the medial head of the gastrocnemius. Examination of the cystic swelling throug this hole revealed soft fibro-fatty material. The roof of the swelling was incised, and after a thinned-ou layer of the medial head of the gastrocnemius had been spread apart, a considerable quantity of fibro fatty tissue welled up from the depths of the belly of the muscle (Fig. 1). There was no definite capsul visible. The entire mass was excised, removing as much surrounding muscle fiber as was feasibl The material shelled out rather easily, and very little bleeding was encountered during its remova Closure of the muscle defect was then performed by several interrupted plain catgut sutures. The dee and superficial fascia were closed in layers with interrupted No. 1 chromic catgut sutures, and the ski was closed by means of continuous black silk sutures. A tight compression bandage was applied. Th postoperative course was uneventful. The patient made a complete functional recovery.

PATHOLOGICAL REPORT

The specimen consisted of an irregular mass of tissue, measuring 6 centimeters in length and 3. centimeters in width. The surface was grayish-yellow in color. The mass was rather firm in consistency In the section, yellowish fat globules were visible. The intervening tissue consisted of grayish-pink firn strands. Some of the peripheral areas showed small grayish-pink fibers which grossly resembled muscl (Fig. 1).

The microscopic section revealed striated muscle tissue, in which degeneration and atrophy ha taken place, with extensive fatty replacement. There was no evidence of malignant degeneration o infection (Figs. 2 and 3).

COMMENT

Although the pathogenesis is not clear, the influence of trauma cannot be denied. I would seem that the sudden application of the patient's body weight upon the extende knee caused a deep rupture within the muscle belly of the medial head of the gastrocnemius with secondary degeneration and fatty-tissue replacement. However, the absence of microscopic hemorrhages or hemosiderin would appear to vitiate this view. It seems mor likely that nerve or vascular damage resulted in infarction with fibrillar degeneration an fatty-tissue replacement. That the lesion is not a lipoma is clearly seen in the microscopi studies (sections taken from the center of the specimen), which reveal fatty tissue, an degeneration and atrophy of muscle fibers throughout. Infection and malignant degeneration were also ruled out by the operative and pathological findings. It is also interesting to note the absence of calcification within the fatty degenerated muscle, despite the fact that operation was delayed for five months after the initial trauma, and good soil fo deposition of calcium was present. Apparently this case does not fall into the group designated as myositis ossificans circumscripta.

CORRECTION

Dr. Raphael R. Goldenberg, of Paterson, New Jersey, has requested that acknowledgment be made that he was in error in including the reference to Watson-Jones in his article, "Closed Manipulation for the Reduction of Fractures of the Neck of the Radius in Children", published in *The Journal* for April 1945 (XXVII, 267). The opening sentence of his article reads: "In the treatment of fractures of the neck of the radius in children, where the displacement is marked, many authorities [reference numbers] believe that only two methods are likely to give satisfactory results,—either excision of the capital fragment or open reduction." Sir Reginald Watson-Jones should not have been included as one of these authorities.

INSTRUMENT FOR ACCURATE MEASUREMENT OF BONE SCREWS

BY MAJOR JOHN J. FLANAGAN
Medical Corps, Army of the United States

In measuring bone depth some time is spent, and occasionally difficulty is experienced, in determining the accurate depth for the insertion of bone screws of proper length. This is true both in the use of bone grafts and of plates employing screws for fixation. While, to assure good fixation, it is necessary to engage the deep cortex, as well as the proximal, penetration of the neighboring soft tissues by the screw tips is undesirable.

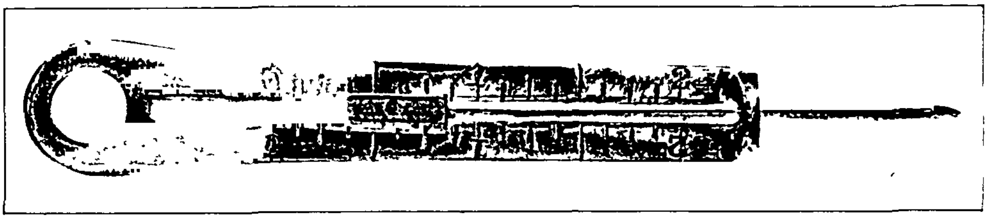

FIG. 1
Instrument open.

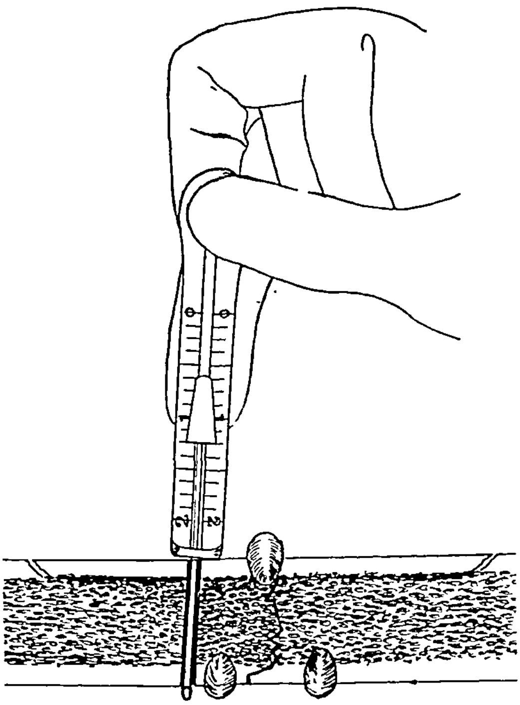

FIG. 2-A
Instrument in use, front view.

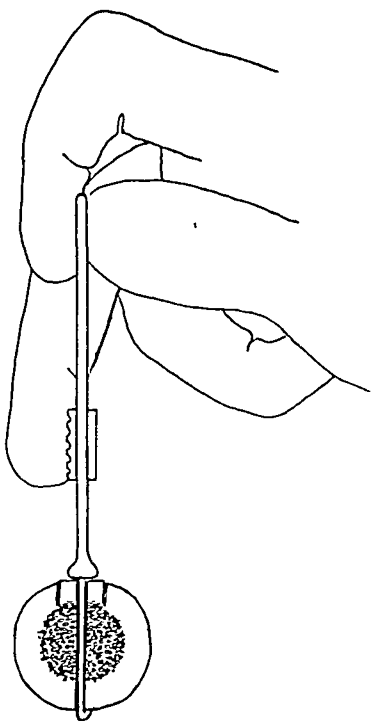

FIG. 2-B
Instrument in use, side view.

The measuring instrument * pictured consists of a sliding rod with terminal hook, which is passed through the drill hole, and engages the deep cortex. The caliber of the sliding rod and hook is less than that of the standard drill hole. The depth is accurately revealed in fractions of an inch on a calibrated scale on the face of the instrument, by means of a marker connected with the proximal end of the sliding rod.

The drawings reveal the instrument in use. It is small and compact, and fits readily into small or deep wounds. It obviates the risk of undermining the soft tissues beyond the deep cortex, while determining accurate depth.

* Designed in the Orthopaedic Instrument and Brace Shop of the Kennedy General Hospital.

A CAST-CALIPER BRACE FOR IMMOBILIZATION OF THE HIP

BY MAJOR GEORGE S. PHALEN

Medical Corps, Army of the United States

In the treatment of War casualties at an Army General Hospital, we have been impressed with the relative frequency of compound fractures involving the acetabulum and the head and the neck of the femur. Many of these fractures are complicated by the development of suppurative arthritis of the hip joint, as well as by chronic osteomyelitis of the acetabulum and the femur. Despite the use of penicillin and the sulfonamides, combined with adequate surgical care, drainage sometimes continues for many months. Cultures of the wounds in these patients usually reveal a penicillin-resistant organism of the *Proteus* group; and in many cases pure cultures of these organisms are obtained.

When the hip joint is involved in a suppurative process, it is necessary to immobilize the joint in order to eliminate pain and prevent the development of deformities. This is best accomplished, of course, by a hip-spica cast; but the encasement of a lower extremity in a plaster cast for a period of several months is certain to result in varying degrees of fibrous ankylosis of the knee and ankle, even though these joints may not have been traumatized at the time the hip was injured. It is the mobilization of these joints, after removal of the cast, that unduly prolongs the patient's period of disability.

Caliper braces with pelvic bands or body corsets, which are used to immobilize the hip, are expensive to build, uncomfortable to wear both day and night, and do not readily

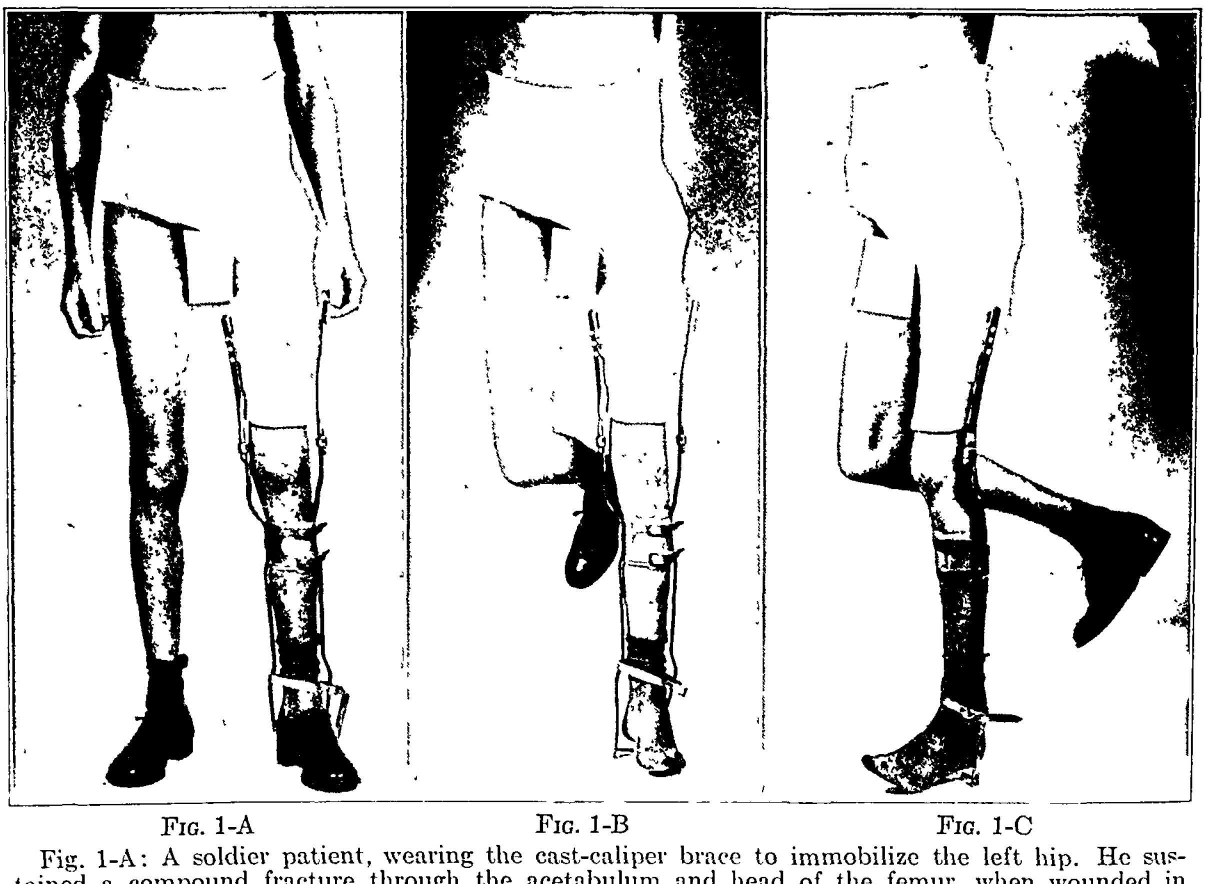

FIG. 1-A　　FIG. 1-B　　FIG. 1-C

Fig. 1-A: A soldier patient, wearing the cast-caliper brace to immobilize the left hip. He sustained a compound fracture through the acetabulum and head of the femur, when wounded in action by a machine-gun bullet. A chronic suppurative osteomyelitis developed, which necessitated prolonged immobilization of the hip joint.

Fig. 1-B and Fig. 1-C: Front and side views of the same patient, bearing his weight on the left leg with shoe removed from the caliper attachment. When the short spica cast is snugly applied, the cast-caliper brace serves adequately as a non-weight-bearing brace.

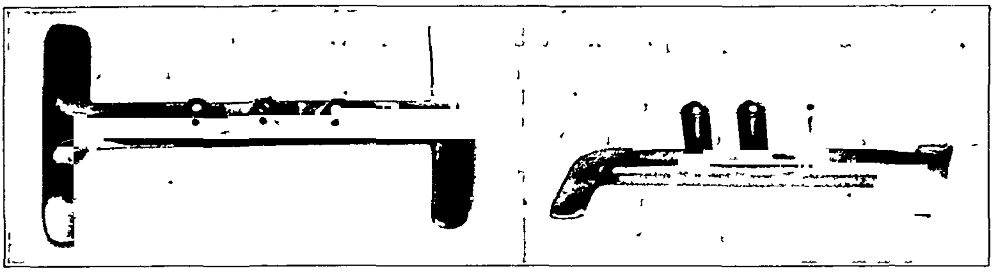

FIG. 2
Front and side views of the metal inserts employed to attach the caliper portion of the brace to the short spica cast These insert bars measure approximately five inches in length.

permit dressing or irrigation of the wounds about the hip. The disadvantages of these braces have been overcome by the use of a single short hip-spica cast, into which is incorporated a long-leg-caliper attachment (Fig. 1-A).

A short, snugly fitting hip spica is applied, which includes the lower thorax, and extends to the knee. It is essential to non-weight-bearing that the cast be molded accurately about the pelvis and the ilia, firmly below the crests. Two metal inserts are incorporated in the leg portion of the cast. These inserts (Fig. 2) are fitted with three bolts, spaced five-eighths of an inch apart, to which the caliper brace is fastened. By means of these inserts, it is possible to adjust the length of the caliper attachment. This caliper attachment is fitted with hinges at the knee, with a stop to prevent extension beyond 180 degrees, and with drop-lock keepers, to hold the joint in complete extension, when the patient is ambulatory.

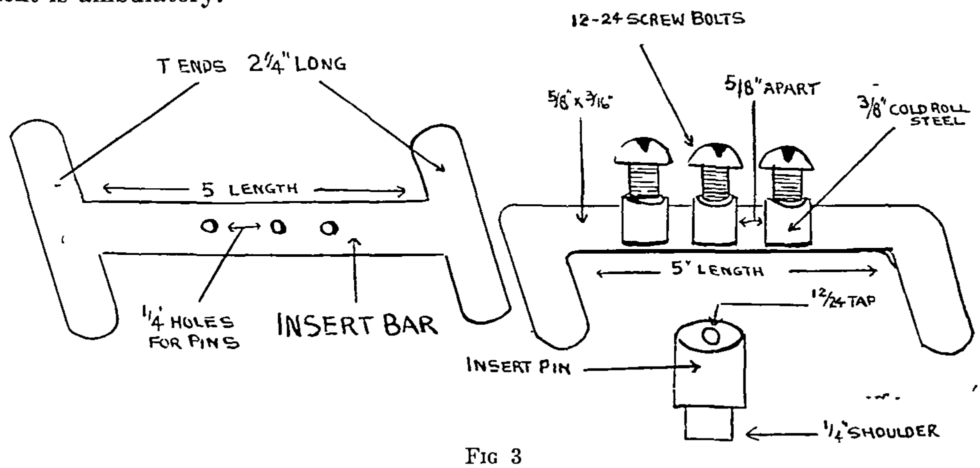

FIG 3
Diagram of the insert bars to which the caliper portion of the brace is attached.

The caliper attachment is fitted into a tube in the heel of the shoe. Although the shoe may be readily removed, it is necessary to wear it both day and night, to prevent rotation of the leg. On occasion, the shoe may be left off at night, and the lower leg bound snugly against the caliper uprights with elastic bandages, in order to prevent external rotation of the lower extremity.

A window may be cut in the spica cast to permit daily dressing or irrigation of draining sinuses about the hip joint. If care is taken to prevent soiling of the cast by the drainage, such a cast may be left on a patient for at least twelve weeks; and then, if necessary, another similar cast may be applied, and the same long-leg-caliper attachment inserted into it.

This cast-caliper brace may serve adequately as a non-weight-bearing splint, by adjusting the length of the caliper attachment. The weight thrust upon the involved lower extremity is transmitted by the caliper uprights onto the short spica cast, which encases

the entire pelvis. The cast-caliper brace thus serves the function of a Thomas ring (ischial weight-bearing) splint, but has the additional advantage of providing immobilization of the hip joint. Patients find that the spica cast is considerably more comfortable for weight-bearing than the ring of an ischial weight-bearing splint.

After the short spica cast has been applied, and the two metal inserts have been incorporated in the cast, a non-rotary, right-angle foot splint may be applied to prevent rotation of the lower extremity, until the caliper attachment has been made. If flexion deformity of the knee is present, it must be corrected before the caliper attachment is applied.

Physical therapy is started as soon as the spica cast has been applied; these treatments consist of heat, massage, gentle forcing of the knee and ankle, and active and passive exercises involving the muscles which move the knee, ankle, and foot. The caliper attachment may even be removed daily, if desired, prior to the treatment, provided the necessary care is taken to prevent rotation of the lower leg.

CONSTRUCTION OF BRACE

Two bars are cut from five-eighth-inch by three-sixteenth-inch strips of flat surgical steel for each side upright. These are hinged together by a lap hinge with a stop to prevent extension beyond 180 degrees, and with drop-lock keepers, made of one-eighth-inch by three-quarter-inch strap steel. This knee hinge is placed just distal to the center of the knee, with the patient lying down. Five holes, seven thirty-seconds of an inch in diameter and five-eighths of an inch apart, are drilled into the portion of each upright above the knee hinge, starting one inch from the top. The upright bars are bent cold to conform to the contour of the leg. The lower end of each upright is drilled, and a section of quarter-inch rod is welded into these holes to fit into the tube in the heel of the shoe. A piece of three-eighth-inch, cold rolled steel rod is cut to proper length, welded to a piece of flat metal, and secured to the heel of the shoe. The rod is set at such an angle in the shoe that the degree of abduction or adduction of the foot will be the same as of the opposite foot. The ends of this rod are drilled out with a quarter-inch drill to permit insertion of the lower ends of the uprights.

The cuff or corset is made of calfskin, lined with horsehide; there are two elkhide straps with nickel buckles. The cuff is cut one and one-quarter inches larger than the circumference of the calf in order to give an overlapping tongue. A metal band, molded to fit the calf, is welded to the uprights back of the leather corset; the corset is riveted to the uprights.

Low-quarter shoes (oxfords) are usually employed. Occasionally it may be necessary to remove the heel counter to prevent skin irritation over a hypersensitive or an anaesthetic heel. In cases of foot-drop, a spring-toe attachment may be applied to the caliper brace.

NOTE: Credit is due Mr. Donald Salmon, Chief Orthopaedic Mechanic at O'Reilly General Hospital, for his assistance in the planning and building of this cast-caliper brace.

News Notes

THE AMERICAN ACADEMY OF ORTHOPAEDIC SURGEONS

The Thirteenth Annual Convention of The American Academy of Orthopaedic Surgeons will be held at the Palmer House, Chicago, January 20 to 23, 1946.

The Instructional Course Program, starting Saturday morning, January 19, will be similar to that planned for the 1945 Meeting (See *The Journal*, XXVI, 842, 843, October 1944). Motion pictures will be presented Saturday afternoon, and the Instructional Section Dinner, with an interesting program following, will be held Saturday evening.

POSTGRADUATE TRAINING IN ORTHOPAEDIC SURGERY

A joint committee of The American Orthopaedic Association and The American Academy of Orthopaedic Surgeons was organized in December 1944, to study the problem of postgraduate training in orthopaedic surgery, and particularly the problem of postwar training for the men in the military services who will, upon completion of their service, need some additional training in order to complete their requirements for certification by The American Board of Orthopaedic Surgery. The formation of this Committee was the outgrowth of numerous discussions among members of the Committee on Postgraduate Training in Orthopaedic Surgery of The American Academy of Orthopaedic Surgeons, members of the Executive Committees of each of the two societies named above, and members of The American Board of Orthopaedic Surgery. Doctor Guy Caldwell, Secretary of The Board, had on numerous occasions pointed out the importance of further developments in the training of men wishing to specialize in orthopaedic surgery.

The training of an orthopaedic surgeon should be along three definite lines: adult orthopaedic surgery, orthopaedic surgery for children, and the surgery of trauma, particularly fractures. It has seemed to the Committee that its main purpose is to encourage the development of centers to cover these three types of training. It was obvious that no adequate survey of the facilities in the country was available. With the aid of men named to report on various sections of the country, the survey has been completed.

The survey shows several things of importance: First, many services which have been important training centers for orthopaedic surgeons are at present not able to train men. Others cannot train as many men as they were able to before the War. The reasons for this are obvious. Many of the visiting men are in the Service, and, due to the quotas of Procurement and Assignment, the number of residencies in most institutions has been curtailed. Second, there have been several institutions which have applied to the Council on Medical Education and Hospitals of the American Medical Association for certification as centers for training in orthopaedic surgery. The Council is covering them as rapidly as possible, and the result of the survey will add a number of institutions to the accredited list. Third, there are a good many places where the material for proper training of orthopaedic surgeons exists, and the men who can conduct such training are available, but for one reason or another the establishment of accredited services has never been carried out.

This Committee feels that its first effort should be directed toward encouraging the organization and certification of services all over the country, where the facilities seem adequate and the men in charge are capable of training orthopaedic surgeons. It is the intention of the Committee to cooperate as closely as possible with the Council on Medical Education and Hospitals of the American Medical Association in order to bring about the certification of such services as seem adequate. It is not the purpose of the Committee, nor has it any authorization, to certify services for orthopaedic training.

In many instances, men returning from the Armed Services to civil life will want additional training of a special type. It is the hope of the Committee that arrangements can be made to satisfy the needs of each and every man as he comes back to civil life, so far as this type of training can be obtained.

Many of the readers of *The Journal* have been approached through this Committee or those aiding in this survey. Many will be in correspondence with the Committee about future plans. A widespread interest in the program has been shown. It is hoped that everyone concerned will feel it his duty to put forth the utmost effort to make this program a success.

The Committee is composed of the following members: Philip D. Wilson, M.D., James S. Speed, M.D., Fremont A. Chandler, M.D., Paul C. Colonna, M.D., Guy W. Leadbetter, M.D., and Ralph K. Ghormley, M.D., Chairman.

THE INTER-AMERICAN ORTHOPAEDIC FELLOWSHIP PROGRAM

The Inter-American Orthopaedic Fellowship Program, directed by the committee of orthopaedic surgeons appointed from The American Academy of Orthopaedic Surgeons and The American Orthopaedic Association, has been functioning for more than a year and a half. The financial support of the program comes from the W. K. Kellogg Foundation, and the Foundation confers with the Directing Committee on all matters of policy.

The Institute of International Education, New York, whose staff have had long experience in dealing with foreign students, both in this country and through its Committees on Selection in other countries, handles most of the foreign correspondence, and also that with the Department of State in Washington. This relieves the Directing Committee of the many details connected with travel, border regulations, temporary residence in the United States, health insurance, *et cetera.*

The purposes of the plan, previously outlined in a simple brochure of information on The Inter-American Orthopaedic Fellowship Program, are as follows:

1. To increase inter-American understanding and to stimulate cultural exchange among the American Republics.
2. To stimulate progress in orthopaedic surgery in the Western Hemisphere, and to serve as a medium for the exchange of knowledge and acquaintanceships in this field among the American Republics.
3. To provide better preparation for orthopaedic surgeons in the American Republics.

Up to the present time, fifteen Latin-American students have come to the United States to take advantage of the fellowships. One student has finished a well-rounded period of orthopaedic training and returned to his home in Brazil. The Republics now represented in this country by fellowship men include the following: Mexico, Brazil, Argentina, Peru, Ecuador, Uruguay, Paraguay, Haiti, Nicaragua, Costa Rica, and Chile. Periodic reports received from these students indicate that they are highly pleased with their opportunities and experiences to date.

Many training centers in the United States have evidenced a willingness to participate in this program. Foreign fellowship men are now, or have been, in training at the following centers: Hospital for Special Surgery, New York City; Children's Hospital, Boston; Lahey Clinic, Boston; Johns Hopkins University, Baltimore; University of Pennsylvania, Philadelphia; Hospital for Joint Diseases, New York City; University of Chicago, Chicago; University of Wisconsin, Madison; University of Iowa, Iowa City; Tulane University, New Orleans; University of Cincinnati, Cincinnati; Willis C. Campbell Clinic, Memphis; Children's Hospital School, Los Angeles; Shriners' Hospital for Crippled Children, Greenville, South Carolina; Charlotte Memorial Hospital, Charlotte, North Carolina; and North Carolina Orthopaedic Hospital, Gastonia.

The first group of students placed in training under this plan came to us on short notice, but it is anticipated that the future policy will be to have a candidate selected, if possible, a year in advance of placement, and the center of training determined before the student leaves home. This program may also be affected by the demand on teaching centers for the further education of men, soon to be released from military service, who desire special orthopaedic training.

The Committee on Inter-American Fellowships in Orthopaedic Surgery, in conjunction with the W. K. Kellogg Foundation and cooperating agencies, desires to function as best it can under existing conditions in meeting some of the demands now being made for fellowships in this country—demands which will undoubtedly be greatly increased in the future—for special educational opportunities in the United States.

The Committee on Inter-American Fellowships is composed of: Dr. George E. Bennett, Dr. Guy W. Leadbetter, Dr. Samuel Kleinberg, Dr. Guy A. Caldwell, and Dr. O. L. Miller, Chairman.

THE BRITISH ORTHOPAEDIC ASSOCIATION

The Spring Meeting of The British Orthopaedic Association was held at Horton Hospital, Epsom, and at Hill End Hospital, St. Albans, on June 1 and 2, respectively, under the presidency of Mr. St. J. D. Buxton. A valuable part of the meeting was devoted to a consideration of the subjects: "Bone and Soft-Tissue Deficiency in the Limbs", "Penicillin", and "Vascular Lesions".

Wing-Commander I. Lawson Dick, Royal Air Force, in "Preliminary Observations on the Use of Cancellous-Bone Transplants", gave an admirable historical survey of the knowledge of osteogenesis in relation to bone-grafting since the time of John Belchier in 1736. He said that the generally accepted view now is that the viability and osteogenetic properties of transplanted bone depend upon the facility with which it can be revascularized. Osteogenesis and viability were long delayed in the depths of massive cortical grafts and most readily ensured in cancellous bone. If the mechanical stability of cortical grafts can be maintained by other means, healing and consolidation will be hastened by the superior osteogenetic properties of cancellous bone. A disadvantage of removing grafts from the tibia

is the not uncommon occurrence of fatigue fractures in the donor bone. The most rapid and surest method of bone transplantation has been with the use of cancellous chips from the ilium.

Mr. S. L. Higgs dealt with "The Use of Cancellous Chips in Bone-Graft Surgery", as a result of his observation of the work of Mowlem in plastic reconstruction of the jaw. He gave a review of seventy-one cases of bone-grafting, sixty for non-union of the long bones. In twenty, cortical grafts alone were used; in forty, cortical bone plus cancellous bone chips were used. All had resulted in bony union, but with cortical grafts alone union had taken at least twice as long as where both types of graft were employed. An exception was the femur, where the average time for healing with cortical grafts alone had been 50 per cent. longer. In the operative procedure it was essential, if cancellous chips were to do their work well and quickly, that rigid fixation be applied. To maintain this, with length and alignment, was the reason for combining a cortical graft with the chips. The methods used for various long bones were described, and the speaker emphasized that there need be no hesitation in excising all sclerosed bone from the site of non-union; similarly, all fibrous tissue could be removed to facilitate vascularization. Any associated skin defects must first be adequately treated by plastic methods.

Mr. Ivor Robertson described the "Treatment of Chronic Infective Osteitis", the essentials of which include a careful but extensive excision of all infected bone and scar tissue and the replacement of tissue loss by bone, muscle flaps, and full-thickness skin grafts. Obviously, such treatment requires careful selection, and the cases described had been of chronic hematogenous osteitis, limited in area and surgically accessible, and cases of chronic osteitis resulting from compound fractures or from war wounds. The treatment was carried out in three stages, with controlled penicillin therapy, and comprised the following procedures: first, excision of the bone and soft-tissue defects and then covering with Thiersch's graft; second, a month later, closure, after this graft had been removed and a full-thickness skin graft substituted; third, at least two months later, bone-grafting. Where an ununited fracture is present, this involves both cortical and cancellous chips. In cases of chronic hematogenous osteitis, the second and third stages may be combined, and iliac cancellous chips alone are packed into the dead space between the walls of the cavity and skin flap. To ensure an adequate blood supply, a muscle flap is swung over them and sutured to the periosteum.

Mr. Rainsford Mowlem discussed "The Problem of Soft-Tissue Defects in the Limbs". He emphasized the need for continuous care of all elements of damage (skeletal, vascular, neuromuscular, and to the skin covering) in all injuries. No element should be ignored, but from every point of view a limb, otherwise intact, is useless without its skin covering. Indeed, fibrosis secondary to infection and exposure will exert an influence upon underlying muscles and joints, which will prevent adequate treatment for these deeper parts and greatly increase the disorganization of the limb as a whole. The use of free grafts and pedicles, or flaps, was discussed. In the former, split grafts can be applied at any time when there is a good vascular surface, usually as soon as possible. For adhesion, maintained pressure is preferable to glue. If the bed is avascular, it must be excised. Infection is not a contra-indication to grafting, so long as it is controlled by suitable chemotherapy. *Bacillus pyocyaneus*, *Proteus*, or *Bacillus coli* infection presents a special problem, but even here successful grafting is not impossible. Exudation is a difficulty, but its mechanical effects can be minimized by using strip grafts or postage-stamp-shaped grafts. After a month, all grafts tend to become dry and to contract; massage with grease will help. Below-the-knee grafted areas require prolonged pressure bandaging to reduce the ill effects of oedema. In weight-bearing surfaces, keratosis may be aided by the use of the sulfhydryl radical. Usually, however, split grafts should be only a preliminary to whole-thickness grafts. The splintage necessary to prevent contracture in grafts on flexor surfaces was discussed. The design, formation, and methods of transplanting whole-thickness grafts were discussed, particularly the possibilities of flap grafts in the primary treatment of certain types of injury, noticeably in the hand. The sites most suitable for particular flap and tube grafts elsewhere, and in secondary treatment, were also discussed.

"The Future of Penicillin Treatment" was discussed by Professor L. P. Garrod, who at the outset contrasted penicillin therapy for bone and soft-tissue lesions; results in the latter can almost be guaranteed, but the story is very different in the former. In the future, more liberal and purer supplies of penicillin should be available. With greater purification, three types of drug are being isolated, the use of which may be specialized according to the type of infection. Improved methods of parenteral administration now give greater comfort to the patient and greater convenience to the surgeon. One of the difficulties of the drug is the rapid dissipation of its effect, and this problem is being investigated by United States workers with the development of suspensions in oil, which are more slowly absorbed. British economy has necessitated the local administration of penicillin, and there is much to be said for the good effects when thus used. Adequate concentration can be achieved where most needed. Economy in the use of the drug hitherto has resulted in the discovery that the effect of penicillin does not depend on its concentration. The full action of the drug is obtained in low strengths; one gains nothing by increasing it, and, in fact, sometimes the reverse effect is produced. The use of penicillin combined with sulfonamides is still under discussion. Professor Garrod's own work, though not conclusive, suggests that the sulfonamides interfere with the effect of penicillin on rapidly multiplying organisms.

Dr. G. F. Kalmykov, Union of Soviet Socialist Republics, discussed the question of "End-Bearing

Amputation Stumps in the Lower Extremity". In the reconstructive surgery of the postwar era, an important field will concern itself with re-amputation, since the practice of emergency primary amputation behind the battlefield leaves definitive amputation to a later date. The extent of this policy varies in different nations. In Soviet Russia, not less than 80 per cent. of re-amputations are required. At one large center in the United States, the speaker found 78 per cent. of re-amputations required. In British hospitals not more than 25 per cent. are required, which is explained by the more frequent flap amputation instead of the guillotine type. Wherever possible, Soviet surgeons seek to create an end-bearing stump by means of an osteoplastic operation. Thus they follow the work of Pirogoff, whose well-known operation in the lower leg is being done in Russia today. Other methods practised are those of Bier in below-the-knee amputations, and the Gritti-Stokes' operation for above the knee. After such operations, it is very important to prepare the stump properly for end bearing. By end bearing, better distribution of weight within the prosthesis is achieved, with consequent improvement in gait and in confidence. Dr. Kalmykov, realizing British conservatism in this matter of end-bearing stumps, made a plea for further work in this sphere.

Dr. M. N. Polonsky, Union of Soviet Socialist Republics, gave a detailed description of a "New Type of Prosthesis in Amputations Through or Near the Hip-Joint", which he thought solved the well-known difficulties of limb-fitting in this region. The advantages claimed were the relative lightness, greater comfort in walking and sitting, and greater economy in manufacturing costs and time. A normal type of above-the-knee prosthesis was employed, fixed to the usual type of pelvic band, from the front of which a broad leather sling passed continuously downward into the front of the prosthesis, over a transversely-placed wooden roller, and out through the back of the limb. It was then attached to the back of the pelvic band, where its tension could be adjusted by lacing. The top of the appliance held a slightly hollowed, springy platform with soft felt lining, upon which the soft parts of the hip gained a shock-absorbing support in walking.

Dr. E. J. Crisp read a paper on the subject of intervertebral-disc lesions, with special reference to early diagnosis and treatment. The lumbar discs suffer trauma more frequently than is generally appreciated, but, in the absence of crural pain or roentgenographic changes, the resulting lesion is frequently mistaken for sacro-iliac strain or fibrositis. The condition may be easily recognized by the extreme and persistent lumbar spasm at first associated with an increase in the lumbar concavity; later, scoliosis to the side of the lesion and lumbar kyphosis develop with sciatic pain. The lordosis occurs when rupture of the annulus fibrosus is incomplete, and the kyphosis when it has completely ruptured. Conservative treatment was advised along such well-recognized lines as the use of the plaster jacket. The essence of Dr. Crisp's views was that persistent lumbar spasm and a "tight" lumbar spine, in an otherwise healthy patient, indicates trauma to a disc and should be dealt with before the onset of sciatica.

Mr. J. E. O'Connell dealt with the "Diagnosis of Lumbar Intervertebral-Disc Protrusions", based upon a postoperative study of 240 patients. Of these explorations, 227 had given positive evidence of intraspinal protrusions. By careful analysis of the clinical picture, it was possible to localize accurately the site of stretching of the intraspinal nerve root, which affected the extradural portion of the nerve root leaving the spinal canal at the intervertebral foramen next below the disc affected. In his series thirty-nine cases had been studied before operation by myelography, with six negative explorations (1[illegible] per cent.). In 201 cases explored without myelography, there had been only seven negative operations (3.5 per cent.). While a variety of conditions can occasionally produce a picture similar to that of a lumbar-disc protrusion, there are only three which do so at all frequently. These are an intraspinal tumor, a metastatic tumor in the lumbar vertebrae, and spondylolisthesis. Clinical examination will help in the differentiation, but certain accessory methods may be necessary. Concerning operative treatment, the speaker emphasized the need for adequate excision of the disc. With proper selection, the results in the majority of cases are excellent. Backache may be frequent, but is rarely incapacitating. There have been a few recurrences, most frequently in the opposite leg.

Professor J. Paterson Ross read a paper, dealing with a series of examples of "Ischaemic Phenomena Following Vascular Injuries" in the lower extremity. He drew attention to the relation of the origin of the sural arteries, supplying the gastrocnemius muscles, to a region of special vulnerability in the popliteal artery. If these and all the terminal branches of that artery were blocked, the leg would probably be useless and sympathectomy would not improve it; pain might necessitate amputation. Where the sural arteries had been blocked, but the collateral circulation preserved, pain in the *upper* calf was troublesome after walking 300 yards. This was relieved by sympathectomy. If the popliteal artery had been damaged below the sural vessels, pain was found only in the *lower* calf and was not appreciably affected by sympathectomy. Block high up in the popliteal artery or femoral artery gives a good leg which can often be improved by sympathectomy, because the vessels to the calf, even if small, are still open. The popliteal artery is vulnerable to direct injury from bone and is liable to "spontaneous" thrombosis, which may be related to less direct trauma and to thrombosis resulting from degenerative changes. In none of the cases described did gangrene occur; but in cases in which the popliteal vein or femoral vein had to be tied, venous congestion was troublesome, and became worse after sympathectomy. In an arteriovenous

fistula. if the main artery was ligated, a good collateral arterial circulation developed *but,* without coincident ligation of the vein, excessive venous drainage rendered the circulation of the periphery precarious. In one case of external iliac-artery ligation in which the arteriovenous fistula had not been recognized. and also in two cases of wounds of the femoral artery and in two wounds of the popliteal artery, immediate paralysis of the common peroneal nerve occurred, suggesting an important additional segmental supply from the popliteal artery.

Major D. Lloyd Griffiths, Royal Army Medical Corps, remarked on the large number of cases of vascular injury to the larger vessels. which he had seen in two years at a variety of centers. He attributed this to the effect of chemotherapy in saving a great many limbs which formerly would have been amputated. In the past, and even now, the ligature of main arteries had been carried out too lightheartedly. His opinion was that a very large proportion, even at reputedly safe sites, had been followed by vicious effects in the periphery,—such as intermittent claudication, incorrigible anaesthesia, and gangrene of the digits. He pleaded for the greater practice of lateral suture of arterial wounds and the avoidance of ligature.

Mr. James Patrick discussed the diagnosis and treatment of seventeen cases of "Fracture of the Medial Epicondyle Displaced into the Elbow Joint". Roentgenographic diagnosis may appear difficult, because the patient is unable to extend the elbow in order to afford a good anteroposterior view. If the medial epicondyle can be seen in the lateral view through the joint line, it can be regarded on this view alone as being incarcerated in the joint. After reduction of the incarcerated fragment, and in all simple fractures of the medial epicondyle, the fragment lies above the level of the joint line and so ceases to be visible in the lateral view. In early cases, reduction can be done easily by anaesthetizing the patient, gently abducting the forearm on the humerus, and applying faradism to the flexor muscles. Fractures not detected for five or six weeks after injury should be treated conservatively. In such cases. the epicondyle eventually develops a bony fusion to the ulna. Anterior transposition of the ulnar nerve is probably unnecessary.

Mr. C. Price Thomas discussed "Scoliosis in Relation to Thoracic Disease". This type of scoliosis follows most commonly upon conditions involving the pleura,—such as chronic empyema and imperfectly treated hemothorax. Pulmonary fibrosis and atelectasis also give rise to the deformity, but do so only when the mediastinum is fixed. The underlying cause is either a concentric pull on the chest wall toward the lung root, or an abnormal intrathoracic negative pressure, or both. There is a striking difference in the chest deformity from that found in primary scoliosis; the intercostal spaces are much more contracted, the curvature of the rib angles is increased, and the anterior part of the chest is flattened on the *concave* side of the scoliosis, the reverse, of course, to that found in primary scoliosis. The impression was also gained that vertebral rotation is less marked in thoracic scoliosis. Mr. Thomas illustrated the types of remedial exercises used, not only in the prevention of the deformity, but also in the course of treating the causal disease and in the after-care of thoracic operations. In some instances, a certain degree of scoliosis was inevitable, because the muscles had lost the rib attachments upon which so much spinal stability depends, but even this condition could be mitigated by remedial exercises.

Mr. A. D. le Vay, in a paper upon "Costoclavicular Compression of the Brachial Plexus", discussed the importance of this factor in the explanation of certain neurological and vascular disturbances in the upper extremity. The conclusions were based upon one case and the recent literature. The patient under discussion had, a year previously, been treated for symptoms of the "scalenus syndrome" (without cervical rib) by the scalenus anterior tenotomy, with consequent aggravation of symptoms. The patient was then operated upon by Mr. le Vay under local anaesthesia, and it was found that the subclavian artery and brachial plexus were very superficial and were bound to the back of the clavicle by dense inflammatory fibrous tissue. The artery was small and transversely grooved, as if just released from a clamp. When the shoulders were braced back, these structures were firmly squeezed between the clavicle and rib; a portion of the latter was excised so that artery and plexus sank back against the pleura. This operation was quickly followed by almost complete recovery.

Dr. Phillippe Bauwens demonstrated a piece of apparatus, devised to make quantitative estimations of action potentials on volition of muscles. The equipment basically consisted of a conventional high-gain amplifier, such as is commonly used for electromyographic explorations, feeding into a loud speaker and a cathode-ray oscillograph. It was modified so that a resistance could be substituted for the coil of the loud speaker, which would act as a non-inductive load of known value.

A system of copper-copper oxide rectifiers, with a choke-capacity reservoir and a microammeter in series with a high resistance, could be shunted across selected portions of this load resistance. The readings on the microammeter bore a relation to the electrical disturbances around the needle electrode inserted into the muscle under examination.

With the controls set in the usual position, the readings obtained for a normal muscle, fully exerting itself against complete opposition, were around 350 microamperes. and were surprisingly constant.

In his introductory remarks, Dr. Bauwens paid tribute to those who had investigated the qualitative aspect of electromyography in peripheral-nerve lesions. and stressed the importance of recognizing the various types of electrical phenomena which characterized normal and abnormal activity in muscle.

In order to assess progress, or the lack of it, it was of advantage to be able to make quantitative estimations of action potentials, and he was satisfied that the measurements obtained by this apparatus were of significance, provided the pitfalls were recognized. In this connection, he pointed out that measurements were related solely to the disturbances immediately around the point of the needle electrode, and that, consequently, one might obtain different readings in different parts of the same muscle. Again, one was dependent on the cooperation of the patient and his ability to direct his efforts into the proper channels. Some of the potentials, registered in muscles with a regenerating motor nerve, were very high and polyphasic. Consequently, they gave rise to unduly high readings, which might prove misleading. It was equally important to ensure that the maximum effort was always being made. The possibility of numerically counting the action potentials by means of an integrating device was under consideration.

Dr. Bauwens thought that electromyographic exploration and the testing of muscles and nerves by means of electrical stimuli were complementary. He demonstrated a valve-operated machine which generated impulses of rectangular wave-form of 1/1000 second, 1/100 second, and 1 second duration. The values of the currents required for a minimal response, using these three impulses, gave an abbreviated intensity-duration curve which was of greater diagnostic value than the indications obtained by the classical method, using interrupted galvanic current and faradic current which defied measurement.

Mr. W. Sayle Creer demonstrated a cinematograph dealing with "Some Foot Faults Related to Form and Function" which, by means of dissections and ingeniously contrived models, illustrated the anatomy and physiology of the foot, its pathology and treatment.

A clinical demonstration was given at Horton Emergency Medical Service Hospital by Mr. St. J. D. Buxton and by members of the staff of that Hospital; by Dr. P. H. Jayes of the Plastic Unit, East Grinstead; Dr. E. E. Harris of the Heritage Craft Schools; Mr. B. H. Burns and Mr. R. H. Young of Bottleys Park; Mr. F. C. Durbin, St. Nicholas Hospital, Pyrford, and Mr. G. N. Goulden, Guildford.

At this meeting the following Associate Members were elected to **The British Orthopaedic Association:**

Capt. Moss Albert, 31 Oakdene Park, Finchley, London, N.3
Mr. K. A. Butler, Lord Mayor Treloar Hospital, Alton, Hampshire
Major G. R. Clarke, 47A High Street, West Bromwich, Staffordshire
Mr. A. J. Craig, 138 Tower Road, Sliema, Malta
Surg. Lt. V. M. Franklin, c/o National Provincial Bank, Ltd., Stratford-on-Avon
Squad. Ldr. K. E. Guest, 38 Davison Avenue, Whitley Bay, Northumberland
Squad. Ldr. J. R. Hughes, Glenwood, Llangollen, North Wales
Mr. E. S. Jamieson, White Lodge Hospital, Newmarket
Lt. Col. W. A. Law, 100th British General Hospital, Central Mediterranean Force
Squad. Ldr. N. Livingstone, Royal Air Force Rehabilitation Unit, Loughborough, Leicestershire
Mr. M. McLearie, 12 Caddle Hill Street, Greenock, Scotland
Squad. Ldr. E. F. Mason, Royal Air Force Rehabilitation Unit, Loughborough, Leicestershire
Major J. M. Quinlan, 53 Queen's Road, Southport, Lancashire
Lt. Edmund Shephard, Ellescombe, Butlers Cross, Aylesbury, Buckinghamshire
Mr. S. A. Sinclair, Beverley Emergency Hospital, Beverley, East Yorkshire
Flt. Lt. E. W. M. Williams, 10 Cardiff Road, Boston Manor, London, W.7

SIR HENRY GAUVAIN

In the April issue of *The Journal* appeared the obituary of Sir Henry Gauvain. In one of the closing paragraphs the author refers to Sir Henry's capacity to inspire happiness and contentment among his patients. Concerning this characteristic of Sir Henry, a reader writes:

"At the time of the German invasion of Belgium in May 1940, the Delcroix Hospital at Ostende had under its care 100 crippled children; plans were hurriedly made for their evacuation by sea to one of the French ports. Before they reached their destination, these ports were in enemy hands and the captain decided to head for England. Aboard this vessel were sixteen Belgian nuns, who cared for these destitute children. When the ship reached Falmouth, it presented the harassed British Government with an additional problem. It was to Sir Henry that the Government appealed. Without any hesitation, he placed the private pavilion of Morland Hall at the disposal of these youngsters; most of them were suffering from surgical tuberculosis, others were victims of infantile paralysis.

"In December 1941, I was in England as Administrator of the American Hospital in Britain and the Chief Surgeon of our Hospital, Dr. Charles H. Bradford of Boston, invited me to accompany him on a visit to Sir Henry. I shall never forget the smiles on the children's faces and the remarks uttered in their native dialect when Sir Henry entered their rooms. He was indeed a great man."

Current Literature

BONE-GRAFTING IN THE TREATMENT OF FRACTURES J R Armstrong M D M Ch, F.R C.S Foreword by R Watson-Jones, B.Sc, M Ch Orth, F R C.S Baltimore, The Williams and Wilkins Company, 1945 $7 00

This 175-page monograph, as its title implies, is not confined to the treatment of ununited fractures, but also includes the use of bone grafts in selected fresh fractures The author gives a concise, accurate, and detailed description of bone-grafting as used in his Royal Air Force Service, which should be of great value to those not thoroughly familiar with the many technical details associated with successful bone transplantation The book is well written and is profusely illustrated with black-and-white and color plates, the former are excellent and the latter are adequate to convey the desired information.

Separate chapters are devoted to bone-grafting of each of the major long bones and of the spine; additional chapters deal with bone-grafting of special fractures, such as fractures of the neck of the femur, of the carpal scaphoid, metacarpals, and malleoli and with fusion of the subastragalar and tarsal joints In general, the author prefers the onlay type of bone graft He recommends the use of bone grafts in certain fresh fractures as an elective procedure, although this is not generally accepted at the present time, a group has been using this method in recent years

A detailed description is given of an original technique for grafting of the carpal scaphoid The author condemns metallic fixation of malleolar fractures because of the alleged injurious effect on the adjacent joint, he feels that bone pegs should be used In fractures of the tarsus requiring fusion of one or more of the tarsal joints, he recommends a "buried" graft, this technique is clearly described, with special reference to operative fusion of the subastragalar joint

In the Appendix, several statistical tables are presented, data are correlated from 1161 fractures, in 76 (6.5 per cent) of which bone-grafting was used

This is a concise monograph which should be useful to the orthopaedic surgeon

INTRODUCCION AL ESTUDIO DE LOS INJERTOS OSEOS (Introduction to the Study of Bone Grafts) Nicolás N Perruelo Buenos Aires El Ateneo, 1945

This well-organized monograph seems to have been written with the particular needs of the busy orthopaedic surgeon in mind, and it is to be regretted that an English translation is not in existence. Most of the work described by Dr Perruelo has been carried on at the Hospital Teodoro Alvarez in Buenos Aires, Argentina, of the staff of which he has been a member for many years

The first section deals with normal bones The second part of the work discusses in great detail the entire subject of bone-grafting, from its early beginnings to the methods now being employed The latter part of the book is given over to the clinical histories of some ninety patients and many excellent roentgenograms are included The illustrations throughout the text are of the highest order, and do much to emphasize the good results obtained by Dr Perruelo

CLINICAL TRAUMATIC SURGERY John J Moorhead B S M D D Sc F.A C S (D S M) Philadelphia and London, W B Saunders Company, 1945 $10 00

Moorhead's justification for compiling a textbook of general knowledge and experience upon a subject which deals with most if not all the specialties is summed up in the statement that trauma "brings surgery to the crossroads"

The book deals with subjects as diverse as war injuries industrial injuries and traumatic neuroses; as technical as fractures of the bones of the face and the relation of trauma to appendicitis, abortion, and visceral displacement, as commonplace as backache and as controversial as medicolegal phases of trauma The bulk of the work is devoted to discussions of fractures and wounds with their complications, but separate chapters deal with amputations injuries of nerves and blood vessels, and deformities of the hands and feet The author constantly emphasizes what he considers to be the simple and fundamental principles, as well as the practical and available measures which apply to the conditions studied He outlines important alternative methods of treatment whenever they are currently accepted, without hesitating to express his own preference

This is distinctly not a book for specialists, yet it contains features which even the specialist will enjoy reading The author has contributed greatly to the art of teaching his subject, because he has clarified and simplified the task of understanding it The specialist may be humbled a little in reading this volume by realizing how small a part of the total problem of traumatology his single department can deal with The presentation of the subject as a whole will help him to switch from an oil-immersion view of his technical field to the lower-powered lenses of common practice The only danger from

such a book is that it might induce surgeons less experienced than the author to assume the role of experts in traumatic surgery, without acquiring the necessary breadth of experience or specialized training for such a practice. The very content of the book shows that traumatic surgery can never be a single specialty; but is rather a field which draws from many specialties.

FISIOPATOLOGIA DEL METABOLISMO OSEO (Pathological Physiology of Osseous Metabolism). Carlos F. de Arazoza. La Habana, Cultural, S. A., 1945. (Biblioteca del medico practico, Volumen XXIII).

De Arazoza has summarized our present-day knowledge of osseous metabolism. He has set for himself three aims: a study of the related metabolism of bony tissue, a review of the factors which intervene in the metabolism of bone, and a study of the diseases in which changes in osseous metabolism take place. While there is little new in the book, it is a careful résumé and digest of data on the chemical changes which take place in bone. Theories of calcification are reviewed. The author adheres to the ferment theory. Phosphatase seems to be essential for the laying down of lime. The roles of calcium, phosphorus, and magnesium are discussed in detail. These salts move rapidly between the blood serum and osseous tissue, as shown by radio-active phosphorus.

The parts played by vitamin A, the parathyroid gland, phosphatase, vitamin D, and vitamin C are described; tables of their physiological action are appended to each chapter. Paget's disease, von Recklinghausen's disease, rickets, scurvy, coeliac disease, osteomalacia, osteopsathyrosis, lipoid diseases of bone, and marble-bone disease are discussed in relation to osseous metabolism.

This little book is a valuable reference for students of diseases of bone. It is well written, and the illustrations are good.

FACIAL PROSTHESIS. Arthur H. Bulbulian, M.S., D.D.S., F.A.C.D. Philadelphia and London, W. B. Saunders Company, 1945. $5.00.

Prosthetic restoration of missing parts of the extremities has long been an accepted orthopaedic procedure, but surgeons know very little about the possibility of prosthetic restoration of deformities of the face and jaws. One reason is that this specialty has been developed by dentists, and reports on such work appear almost exclusively in dental periodicals and books. Moreover it is a highly specialized subject, and consequently very few members of the dental profession have taken the training necessary to enable them to contribute to the solution of facial and maxillary problems.

Prosthetic methods of reconstruction have received a good deal of attention since World War I. Knowledge gained at that time was used successfully by surgeons in the repair of deformities resulting from malignant diseases of the face and jaws.

This concise book on facial prosthesis undoubtedly will fill a great demand, because at the present time there is more interest in the subject than ever before. The scope of the book, however, is limited to a discussion of artificial restoration of the face, especially the ear, nose, and orbit. It does not cover reconstructive measures for maxillary defects, which are often part of such deformities.

As the author plainly states, the repair of facial deformities is primarily a surgical problem, but there are numerous conditions and circumstances which make surgery impossible or inadvisable. In such cases, artificial restoration, temporary or permanent in nature, of the missing parts of the face becomes desirable. The author has somewhat overemphasized the use of latex as a suitable material for restoration, this reviewer believes, and has not given enough importance to other materials, such as acrylics.

The book is divided into fourteen chapters, and the classification of subjects is excellent. There are numerous diagrams and illustrations to help the reader in understanding the techniques of restoration. It is a good, small book to introduce prosthetic concepts and techniques to those interested in restorative problems of the face.

ÜBER OSTEOMYELOSKLEROSE (OSTEOMYELOSCLEROSIS). G. A. Landoff. *Acta Radiologica,* XXV, 81, 1944.

Apart from Albers-Schönberg's disease, the clinical entity of the various forms of osteosclerotic anaemia are but little known. Most commonly they are recognized only at autopsy, because of the absence of any characteristic clinical picture.

In the author's case and the sixteen which he reviews from the literature, the disease occurred primarily in adults beyond the age of fifty. The blood picture is not typical, but is in general that of a progressive anaemia. The white cells show all variations from that of complete aleukaemia to that of myeloid leukaemia. The sedimentation rate is increased.

Opinions vary as to the nature of the disease in the bone. Some consider that atrophy of the marrow is associated with extra-osseous blood formation. Others consider that the picture is dominated by fibrosis of a leukaemic marrow.

The bone changes affect only the spongiosa; Wolff called it an "endosteal hyperostosis with metaplastic bone formation". Microscopically it is found that the bone trabeculae are less numerous. There is evidence of new-bone formation, but the osteoblasts and osteoclasts are strangely absent. The marrow cavities are fibrotic with occasional clumps of myeloid and erythropoietic cells.

Roentgenographically the disease is characterized by the appearance of broader, well-defined spongiosa trabeculae, with narrowing of the marrow cavity. This is best seen in the vertebral column and the pelvis. In the opinion of the author the condition is to be considered as the earlier phase of the disease known as "marble bone".

It may be differentiated from metastatic carcinoma by the more widespread osseous involvement. It may be differentiated from chronic fluorine poisoning by the absence of spotty cortical thickenings, calcification of the ligaments, and osteophyte formation. No therapy is effective.—*Henry Milch, M.D., New York, N. Y.*

De la forme kystique des métastases cancéreuses des os (Cystic Form of Metastatic Carcinoma of Bone). Bengt Engfeldt. *Acta Radiologica,* XXV, 317, 1944.

The cystic form of osseous metastases from carcinoma is apparently very rare. In the literature are reported one case derived from a carcinoma of the prostate, one from carcinoma of the oesophagus, and two from carcinoma of the breast. The author adds a case in which the primary site was the lung.

The widespread osseous metastases caused absolutely no symptoms, and were discovered in the course of autopsy. The cysts were lined with cancer tissue, and were well demarcated from the surrounding tissue. The author reviews the theories which had been advanced to explain the formation of cysts in metastatic carcinoma.—*Henry Milch, M.D., New York, N. Y.*

Über einen mit Röntgenstrahlen behandelten Polymyositisfall (Case of Polymyositis Treated by Roentgenotherapy). Hugo Ahlbom. *Acta Radiologica,* XXV, 403, 1944.

Polymyositis or dermatomyositis is a rare disease first described in 1890. It presents the appearance of an acute infection with intermittent course. Inflammation of the back and extremity muscles is most common. The etiology is unknown and the prognosis is bad.

The author recommends the use of small doses of roentgenotherapy. If these are unsuccessful, he advises the use of large doses. A case is reported in which this type of treatment appeared to have given good results.—*Henry Milch, M.D., New York, N. Y.*

Roentgen Treatment and the Course of Cure of Giant Cell Tumor in the Osseous System. Gösta Jansson. *Acta Radiologica,* XXV, 569, 1944.

Roentgenographically the local fibrocystic diseases may be divided into three types: "(1) the bone cysts occurring in young persons under the age of fifteen, and involving the metaphyses; (2-a) the benign slow-growing cell tumors occurring in patients between the ages of twenty and forty, and involving the epiphyses; and (2-b) the strongly progressive epiphyseal type of giant cell tumors, in which the osteolysis develops quickly, and which appear locally malignant".

It is the opinion of the author that roentgenotherapy is the method of choice in the treatment of this condition. He cautions against the combination of surgery and roentgenotherapy. He notes that excessive radiation is often harmful, and may lead to initial osteolysis of the involved bone.—*Henry Milch, M.D., New York, N. Y.*

Fall von Chondrodystrophia congenita calcificans (A Case of Chondrodystrophia Congenita Calcificans). Sigvar Jorup. *Acta Radiologica,* XXV, 580, 1944.

This disease was first described by Conradi in 1914. It appears to belong to the general category of the foetal chondrodystrophias, but is very rare. The disease occurs in the newborn, and is characterized by the appearance of small localized calcium deposits in the epiphyses of chondrogenous bones. In one case in which pathological material could be studied, small areas of chondromalacia with calcium depositions were found. As a consequence, a moderate micromelia, affecting primarily the lower extremities, has been observed.

The prognosis in these cases is apparently determined by other malformations which are associated with it. As regards the growth of the bones, the prognosis appears not unfavorable, and in this respect a marked difference between this disease and the classical type of chondrodystrophy is to be noted.

The patient here reported was first seen at the age of twelve days, and has been followed for a period of fourteen months. A number of interesting roentgenograms illustrate the article. A review of previously reported cases is given.—*Henry Milch, M.D., New York, N. Y.*

The Instability Associated with Disk Degeneration in the Lumbar Spine. Folke Knutsson. *Acta Radiologica,* XXV, 593, 1944.

"Examination of anatomic specimen of the lumbar spine has shown that disk degeneration (osteochondrosis) causes abnormal movements between the vertebrae (Hildebrandt, Guntz) and it has been assumed that clinical symptoms of disk degeneration are due to this instability. Putti aptly likened the condition to pseudo-arthrosis."

The author notes that the ordinary roentgenographic examination, made with the patient recum-

bent, is intended for the study of anatomical conditions. In order to establish functional capacity, he recommends making roentgenograms "with the patient standing and bending as far forward and backward as possible". With these complementary pictures, the roentgenographic diagnosis of disc degeneration may be made on the following findings:

1. Narrowing of the intervertebral space;
2. Reactive changes, such as sclerosis of the vertebral surfaces and lipping of the margins;
3. Vacuum phenomena, visualized as fissure spaces in the discs on backward bending;
4. Abnormal position of the vertebrae in relation to each other;
5. Abnormal motion of the vertebrae.

The exposures are made in the following manner:

1. Standing at the edge of the table, the patient extends the spine maximally while a lateral view is made.
2. Sitting on the edge of the table, the patient flexes the spine maximally while a lateral view is made.

Roentgenograms were made at a distance of one meter.

Normally, flexion or extension of the spine leads to unilateral compression of the disc on the concave side. When the disc is injured, this shock-absorbing function is impaired, and in its place the vertebra is displaced in the direction of motion. The fifth lumbar vertebra is apparently an exception to this rule. While retroposition occurs in extension, it is accentuated in flexion also. The author attributes this to other factors which he does not discuss.

By these methods the author believes he can diagnose disc instability before anatomical signs appear.—*Henry Milch, M.D., New York, N. Y.*

A CONTRIBUTION TO THE TREATMENT OF FRACTURES OF THE POSTERIOR BORDER OF THE TIBIA BY MALLEOLAR FRACTURES. Gunnar Nyström. *Acta Radiologica,* XXV, 672, 1944.

The statistics of Hendelberg have conclusively demonstrated the unfavorable prognosis of fracture of the posterior lip of the tibia (third malleolus). In those cases in which this fragment includes one third or more of the articular surface, a displacement of more than two millimeters, a bad result with invalidism may be expected.

The author reports his percutaneous method of fixing such a fragment. The fracture is reduced, and a plaster-of-Paris boot is applied. A window is then cut over the heel and the Achilles tendon. Under the fluoroscope, a common carpenter's awl is introduced, and the posterior fragment is levered into position. The awl is removed, and the fragment is fixed by a Kirschner wire which is cut off and incorporated into the plaster. The wire is removed after about one month, and weight-bearing is gradually begun. The plaster is removed six weeks after operation.—*Henry Milch, M.D., New York, N. Y.*

ARTHROGRAPHY OF THE MANDIBULAR JOINT. Flemming Nørgaard. *Acta Radiologica,* XXV, 679, 1944.

Roentgenography of this joint presents many difficulties. In an effort to overcome some of these, particularly in cases where non-osseous lesions exist, the author has employed perabrodil or uroselectan in thirty-four cases.

With the patient supine, head turned to one side, mouth open, the skin midway between the tragus and the condyle of the mandible is anaesthetized with novocaine. The needle is then pushed into the lower part of the mandibular joint. About one cubic centimeter of a 35 per cent. perabrodil solution is then injected, and an exposure is made. Thereafter the upper part of the joint is injected with from 1.5 to 2 cubic centimeters of the same contrast substance.

The patient experiences a sensation of painful tension and inability to shut the mouth in a normal manner; this sensation usually disappears quickly, sometimes within a day. Only one joint is examined at a time. The second joint may be examined after an interval of several days, preferably a week. A more complete report of the work will be published after more data have been accumulated.—*Henry Milch, M.D., New York, N. Y.*

TESTE COLORIMETRICO PARA AVALIACÃO DA CAPACIDADE CIRCULATORIA E DA VITALIDADE DE UMA REGIAO (COLORIMETRIC TEST FOR EVALUATION OF THE CIRCULATORY CAPACITY AND THE VITALITY OF A GIVEN REGION). Mario Ottobrini Costa. *Anais Paulistas de Medicina e Cirugia,* XLVIII, 193, 1944.

In the matter of amputations consequent upon arterial obstructions, the question as to economically delayed amputation or immediate amputation has always been difficult to solve. Many different tests, oscillometric, colorimetric, thermometric, have been devised, but none gives any positive evidence as to the extent or the importance of the collateral circulation.

In an attempt to establish clinical rules to guide amputations, Quénu recommended: (1) amputation of the toe for gangrene of the phalanx, (2) amputation of the foot for gangrene of the toe, and (3) amputation of the lower third of the leg for gangrene of the forefoot.

In May 1935, the author attempted to accumulate positive evidence on this problem by injecting various types of chromatic substances into the arterial trees of animals.

As it is being employed at present, arteriochromia is performed in the following manner: The main artery of the upper or lower extremity, femoral or humeral, is palpated and punctured by a long thin needle, directed into the axis of the vessel. Five cubic centimeters of "Pimecral", apparently a proprietary drug, or five cubic centimeters of a 2 per cent. solution of "trypoflavin" are slowly injected. Directly thereafter, discoloration of the skin will be noted in the area of the distribution of the artery. The intensity of the discoloration as well as the upper and lower limits are carefully noted as a guide to the probable area of satisfactory vascularization.—*Henry Milch, M.D., New York, N. Y.*

TRATAMENTO DAS FRATURAS DO COLO DO FEMUR (Treatment of Fractures of the Neck of the Femur). Barros Lima. *Arquivos Brasileiros de Cirurgia e Ortopedia*, XIII, 57, 1944.

A very comprehensive study of fracture of the neck of the femur is given, including the mechanism of fracture and reasons for failure. Various methods of treatment are critically reviewed, and the method of Godoy-Moreira is described in some detail.—*Emanuel B. Kaplan, M.D., New York, N. Y.*

SINDROME DE KLIPPEL-FEIL (KLIPPEL-FEIL SYNDROME). Antonio R. Grasso. *Boletín de la Sociedad de Cirugía del Uruguay*, XV, 198, 1944.

As a result of observations made on a girl, nine years old, in whom torticollis was the primary symptom, the author undertook a review of the Klippel-Feil syndrome. Clinically the cases thus far reported may be divided into:

1. Abortive type, including cases which are symptomless until the diagnosis is accidentally made, following injury or some intercurrent infection;
2. Mild type, including those cases in which torticollis, elevation of the scapula, or cervicodorsal scoliosis constitute the prominent symptoms.
3. Classic type, including the characteristic "man without neck". Clinically this form is characterized by the symptom triad: absence of neck, low implantation of hair, and limitation of motion in the cervical spine.

These symptoms, resulting from the anatomical malformations of the cervical spine, are associated with a number of accessory symptoms: descent of the lobule of the ear; descent of the mammary areolae; descent of the mandible and consequent difficulty in opening the mouth; malformation of the thorax; cervicodorsal scoliosis and kyphosis; and neurological symptoms involving the cranial and peripheral nerves.

Roentgenographically the condition is characterized by: reduction in the number of cervical elements; anomalies, such as spina bifida; vertebral synostosis; aplasia-hemispondylia or platyspondylisis of the cervical vertebrae; reduction in the number of ribs; and sacralization and spina bifida of the fifth lumbar vertebra.

Anatomically, all the variations seen in Klippel-Feil syndrome may be attributed to embryological arrest in development. Apart from those monstrosities which are incompatible with normal existence, the prognosis for life is good. In those cases in which peripheral-nerve symptoms arise from the presence of a cervical rib or an enlarged apophysis, surgery is indicated.—*Henry Milch, M.D., New York, N. Y.*

PLASTICITY OF BONE. James F. Brailsford. *The British Journal of Surgery*, XXXII, 345, 1945.

The features of a perfect model are preserved by the balance of muscular tension and the strength, hardness, rigidity, and resilience of the bone. The features are changed if the balance is upset. As a result, the affected elements bend and certain characteristic deformities are produced, unless steps are taken to neutralize the abnormal influence. Before mineral matter is deposited in pre-osseous tissue, it is plastic, and it can be compressed and deformed by stresses and strains, although it is not altered by such stresses and strains in the normal growing child.

"With the cessation of function, occasioned by paralysis, there occurs a gradual decalcification of the bones of the affected part." This may occur in the spine or in an extremity. In osteogenesis imperfecta there is atrophy of the shafts of the bones with normal growth or overgrowth of the diaphyses. The skeleton shows plasticity, and is altered by muscular or gravitational pull.

Plasticity may be due to generalized changes in the bone, as in osteogenesis imperfecta and in renal rickets, or to changes localized to one portion of the skeleton, as in Paget's disease. Trauma may cause localized plasticity. During some of the stages of osteochondritis the bone is soft and requires protection from weight-bearing.—*Ernest M. Daland, M.D., Boston, Massachusetts.*

OSTEOMYELITIS OF THE CLAVICLE. Tina Gray. *The British Journal of Surgery*, XXXII, 466, 1945.

This is a case report of a boy of twelve. At operation for drainage of osteomyelitis of the clavicle, it was found that the entire bone had sequestrated and it was removed. The boy had no disability following removal, and the wound healed rapidly. Complete regeneration of the clavicle occurred.—*Ernest M. Daland, M.D., Boston, Massachusetts.*

PLASMOCYTOMA OF BONE. William Tennent. *The British Journal of Surgery*, XXXII, 471, 1945.

Plasmocytomata are rare tumors composed of plasma cells or their immediate precursors. They arise in the lymphatic tissue of the nasopharynx and in bone marrow. Plasmocytoma of bone occurs in the marrow of flat bones, long bones, and vertebrae, but has not been reported in the small bones of the hands or feet. The commonest sites are in the ilium and the proximal ends of the femur and humerus. The writer found forty-nine cases reported in the literature, and presents a fiftieth case.

A male of fifty, being treated for pneumonia, was found to have a deep mass in the right iliac fossa, tender to pressure and fixed to the posterior abdominal wall. Roentgenograms showed a destructive process in the right ilium. The cortex was expanded, but not destroyed; and the tumor was limited to the bone.

Biopsy showed a plasmocytoma. Roentgenograms of other bones revealed no other lesions. Roentgenotherapy was advised but refused. The patient was not seen again until two years later, at which time he stated that for three months he had suffered from ache at the site of the original tumor, general weakness, loss of weight, and shortness of breath. At times he had had pains in both arms and legs.

Roentgenographic examination showed multiple areas of rarefaction in the left femur, skull, ribs, and both humeri. These had the typical appearance of multiple myelomatosis. Bence-Jones proteose was present in the urine.

A few weeks later the patient died. From his history it was gleaned that he had had symptoms referable to his hip and pelvis for three years before the tumor was discovered. It was apparent that this process had gone on for five years before it assumed the characteristic picture of multiple myelomatosis. Such a terminal outcome is to be expected, if the original tumor is untreated.

Study of the other cases in the literature shows that they have been treated by radiation, curettage, and amputation. Because of lack of adequate follow-up, no decision can be made as to the best methods of treatment.—*Ernest M. Daland, M.D., Boston, Massachusetts.*

TREATMENT OF WOUNDS BY DELAYED SUTURE. William Patrick. *British Medical Journal*, II, 788, 1944.

In the author's group of three series of cases (ten, twenty-eight, and eighteen, respectively), forty-seven wounds out of fifty-six were healed completely within three weeks of suturing, and twenty-eight of the forty-seven wounds were healed by first intention on the tenth day. Penicillin and sulfonamides were used in combination in the first two series, sulfanilamide alone in the third. The best results were obtained when the two powders were combined.

Causative missiles had been mainly high-explosive shell or mortar shell, but the nature of the missile had no obvious effect on healing; nor was the healing process affected by the location, situation, or direction of the wound. A strong bacteriostatic powder with a longer time interval before suture produced better results in the first and second series than a weaker powder and a shorter time interval in the third series. Occasionally, on the tenth day, a wound was discovered to be a little red and "grumbly" at the stitch holes, but with a firm suture line; this very mild degree of infection never proved to be of any significance, and at the subsequent dressing on the sixteenth day, the wound was usually found to be dry and healed. Extra dressings were done when indicated.

AMPUTATION OF THE EXTREMITIES, AND PROSTHESIS, IN THE U.S.S.R. Nikolai N. Priorov. *British Medical Journal*, I, 178, 1945.

The majority of amputations in the Soviet Army are performed at the front, and only one-fifth in hospitals in the rear. Reasons for amputation include severe destruction and crushing of soft tissue, bones, and joints (up to 40 per cent.), almost complete tearing away of the limb by bomb or shell fragment, gas infection, gas gangrene, and sepsis.

Both chop and guillotine methods of amputation are used, the latter being preferred. Primary amputations are not sutured. Prepared flaps are rolled into tube form and sutured, to be used later. Safeguards obligatory in amputations include heat, blood transfusion, a tourniquet, anaesthesia, and sulfonamides.

Up to 80 per cent. of amputation stumps are diseased or defective. Diseases comprise non-healing wounds, ulcers, osteomyelitis, ligature fistulae, exostosis, neuritis, pains in the stump, phlebitis, disorders of the skin, and contracture. Defects consist of excessively long or short stumps, disarticulated stumps of the knee joint, ankle joint, wrist, and shoulder, stump scars with bone adhesions, conical stumps, ankylosis, and defects following osteoplastic operations. Cases that do not respond to conservative measures are treated by skin-grafting, by grafting adjacent tissue, by excision of scar tissue with skin-grafting, by removal of adhesions and ligatures, by removal of neuromata and neurolysis, by sequestrectomy, or by re-amputation. Indications for re-amputation have occurred in non-healing wounds up to 60 per cent.; in osteomyelitis, from 17 to 20 per cent.; in extensive scars with bone adhesions, 10 per cent.; and for exostosis and pains, 10 per cent. The bone canal, in re-amputation, is tamponed with a section of muscle. The stump is carefully prepared for a prosthesis for two to three months by stump exercises, physiotherapy, gymnastics, stump wrapping, and training to accustom the stump to withstand pressure.

Up to 90 per cent. of amputees, after being treated and supplied with artificial limbs, return to the factories, plants, and other establishments, where they were employed prior to the war.

Osteoplastic Re-Amputation of the Thigh. Alexander Kotov. *British Medical Journal,* I, 179, 1945.

End-weight-bearing stumps are preferred to other types by many Russian surgeons from the prosthetic point of view. Below-the-knee amputations are considered to provide the best means of obtaining end-weight-bearing stumps by operative procedure. The Pirogov, Syme, Bier, and Kirschner operations are used in below-the-knee re-amputations.

In re-amputation of the thigh, the Gritti-Stokes amputation gives a good result in the lower third of the thigh. A new technique has been devised, where this operation cannot be used, to obtain a pressure-bearing thigh stump. A flap of skin sufficient to cover the lower surface of the stump is cut from the anterior aspect of the thigh. The skin on the posterior surface is divided almost perpendicularly to the bone of the extremity. The muscle layers are divided conoidally, and the bones of the thigh are cut through. A ring-shaped bone transplant, 0.5 to 0.75 centimeter thick, is cut from the proximal end of the amputated bone, and is introduced in whole or in sections into the bone-marrow canal. The muscles are then stitched in layers, and the skin is sutured. During ten months of work, fifteen osteoplastic re-amputations of the thigh stump in the middle third were performed by this technique. The postoperative wound healed quickly. On the twelfth to fourteenth day after the operation, daily exercises were begun, to educate the stump to weight-bearing. The amputee was supplied with crutches, fitted with a platform for supporting the stump, at the beginning of the second month after operation. The walking time was increased daily. Later, end-weight-bearing prostheses, having free mobility of the knee joint, were provided.

Peritendinitis, or Foot-Sloggers Nodule. H. Daintree Johnson. *British Medical Journal,* I, 193, 1945.

Peritendinitis presents itself as a painful swelling over a tendon and corresponds to a point of pressure, such as a fold in the leather of a boot. Pain comes on during a march, and the lesion may occur on the Achilles tendon, the tendon of the tibialis anterior, or the flexor tendon of the hallux. It gradually becomes a well-circumscribed elevated nodule, or two nodules with a groove between. The nodule is closely adherent to the skin, but can be lifted off the tendon. The commonest site is over the Achilles tendon. The crease in the soldier's boot projects forward and the lesion is caused by repeated indentation. For treatment, the author suggests stiffening the back of the boot with a tin splint, which is clipped on (illustrations are given).

A nodule over the tibialis anterior tendon is produced by that cross-piece of the lace most nearly opposite to the ankle joint. The soldier should be taught to lace his boots so that the laces do not cross the tendon beneath the leather, but only in front of it. A strip of felt should be inserted behind the tongue of each boot.

If a crease has formed just behind the toe-cap of the boot and caused peritendinitis over the base of the hallux, the lesion may be relieved by the insertion of a piece of felt, which will cause the leather to fold outward instead of inward. The patient may have to be excused from wearing boots altogether or given footgear that does not cause pain.

Recurrent Dislocation of Ankle Due to Rupture of External Lateral Ligament. E. Hambly. *British Medical Journal,* I, 413, 1945.

An operation for recurrent dislocation of the ankle due to rupture of the external lateral ligament is reported. The ligament is repaired by splitting the peroneus longus tendon from above downward. The detached end is threaded through the lateral malleolus and through the os calcis, and back again on itself. This reconstitutes the ligament.

A case report is given in which the operation was successful. The patient has had no further trouble.

Stabilization Operations of the Foot. A. K. Basu. *Calcutta Medical Journal,* XXXIX, 9, 1942.

Basu describes and compares seven operative procedures for production of a firm painless foot suitable for weight-bearing and progression. These operations are: (1) Whitman's astragalectomy, (2) Dunn's triple arthrodesis, (3) Hoke's operation, (4) Lambrinudi's operation, (5) subastragalar arthrodesis, (6) Campbell's operation, and (7) Putti's operation. The chief indications for such procedures are: (1) postparalytic flail-foot following poliomyelitis, (2) congenital club-foot, (3) peroneal-nerve injury, and (4) fracture of the talus or calcaneum. The author also reports two cases of astragalectomy, one of Dunn's operation, and two of subastragalar arthrodesis. The article seems of unusual interest.—*Robert M. Green, M.D., Boston, Massachusetts.*

Internal Fixation of Fractures of the Neck of the Femur. Duncan W. Boucher. *The Canadian Medical Association Journal,* LII, 31, 1945.

The author reports the use of the three-flanged, centrally canalized nail, in the internal fixation of forty-seven fractures of the neck of the femur. Subcapital fracture occurred in 16.2 per cent., transcervical fracture, in 41.8 per cent., and basilar fractures, either intertrochanteric or pertrochanteric, in 41.8 per cent. The ages ranged from fifty-four to eighty-nine years, with most in the eighth decade.

The fractures were more common in women than in men, 83.2 per cent. as compared with 16.7 per cent. Nineteen patients, or 40 per cent., had complications on admission, which affected the end result.

Anaesthesia was induced, in most cases, with nitrous oxide and oxygen; in some, with a spinal anaesthetic; and in one, by local infiltration. Roentgenograms guided the procedure, before, during, and after the operation. Extra-articular technique was followed in the introduction of the three-flanged nail, with the thigh in a position of abduction, hyperextension, and in internal rotation, and with the knee preferably fully extended. The guide wire was inserted well into the head of the femur, and the nail was threaded over the wire, and hammered home. Vigorous movements were then carried out by the surgeon to test the thoroughness of the operative procedure. Smooth movement, without recurring deformity, indicated solid impaction.

Patients were up on about the fourth day, and were bearing weight on the injured limb by the ninth week or sooner.

The end results were good in 72.3 per cent., fair in 8.3 per cent., bad in 8.3 per cent.; and 10.6 per cent. died. No nails were extracted, except in those patients who died while in the Hospital, and in one case of absorption of the neck of the femur.

Estudio de la sinapsa mioneural experimentalmente y en biopsias de músculos humanos paraliticos (Experimental Study of Myoneural Function in Biopsy Specimens Taken from Muscles of Poliomyelitic Patients). J. Sanz Ibáñez. *Cirugía del Aparato Locomotor,* I, 193, 1944.

Ibáñez, working in the Cahal Institute, studied the myoneural functions in biopsy specimens, taken from muscles of patients with poliomyelitis and from experimental animals in various stages of the disease. He found two groups of paralyses: (1) paralysis of central origin, irreparable, due to destruction of the nerve cells of the anterior horn of the medulla, (2) paralysis of peripheral origin, reparable, due to changes in the nervous components of the motorial plate. In the second type, regeneration is capable of restoring movement in the paralyzed muscles.

In guinea pigs, febrile infections were found, unaccompanied by paralysis. Other animals were observed, in which there was neither paralysis nor fever. In these cases, the plasma of the animals neutralized the virus of poliomyelitis. The author concludes that three forms of the disease occur: (1) fever with paralysis; paralysis may be central or peripheral; (2) fever without paralysis; (3) disease without either fever or paralysis. Biopsies of muscles in various stages of paralysis showed the development of arborization of nerve filaments, which to the author suggested repair, and explained the recuperation of function in certain cases.—*John G. Kuhns, M.D., Boston, Massachusetts.*

El sarcoma osteogenico (Osteogenic Sarcoma). L. Sierra Cano and F. Lopez Areal. *Cirugía del Aparato Locomotor,* II, 1, 1945.

The authors review the cases of osteogenic sarcoma seen at the Institute of Health at Valdecilla. Thirty patients were seen between 1930 and 1944, seventeen of whom were twenty years of age or less. Trauma played a rather insignificant rôle in the onset. Following the considerations of Segond—previous injury at the site of the tumor, sufficient severity of the injury, development of the tumor in the traumatized tissue, continuity of the relationship between the injury and the tumor (one month to two years)—nine case histories are discussed, in which there was a probable relationship between the lesion and an injury. The tumors studied were located chiefly in the lower extremity, seventeen in the femur, five in the tibia; twenty-four were located about the epiphyseal line. Generalized adenopathy was found in eight cases. Three cases were mistakenly diagnosed as osteomyelitis.

In these patients early surgical intervention was practised. Amputations were performed upon fifteen, and disarticulations upon five. Only three of the patients upon whom amputations were performed lived over two years; and of the five patients having disarticulations, only one lived over two years.

This result is in accord with the statement of Ferguson that early amputation is fatal. It should be deferred for at least seven months from the onset of symptoms. Survival has depended more upon the type of tumor than upon the method of treatment, so that no categorical answer can yet be given in regard to the best treatment.

In seven cases, pulmonary metastases were the first symptoms which the patient showed. The cause of death in all cases was systemic metatases of the tumor.—*John G. Kuhns, M.D., Boston, Massachusetts.*

Disepifisiplasia vertebral (el cifosis dorsal juvenil) [Epiphyseal Dysplasia of the Vertebrae]. V. Sanchis Olmos. *Cirugía del Aparato Locomotor,* II, 97, 1945.

Olmos reviews the histories of twelve cases of juvenile dorsal kyphosis (Scheuermann's disease). He reviews the various etiological considerations: heredity, constitutional weakness, trauma, and endocrine disturbances. The author believes with Schanz that muscular insufficiency predisposes to this condition, which is then followed by cartilaginous deformity. Beginning deformity changes the balance between the stimulus of traction and of pressure. The changes in the intervertebral discs and the marginal proliferation about the bodies follow the earlier epiphyseal changes. The vertebral epiphyses are not such

as are found in long bones, but are secondary nuclei of ossification such as are found in the os calcis. The term juvenile dorsal kyphosis is meaningless. Osteochondritis and epiphysitis are false, since no evidence of inflammation is found. The same can be said of localized malacia. Vertebral epiphyseal dysplasia most completely describes this disturbance. These lesions are of great importance in the development of senile kyphosis and spinal arthritis deformans.

For treatment during the early stages, the author advises rest on a hard bed until pain disappears, the use of heat, massage to the spinal muscles, and local infiltration with novocaine. This is followed by exercises to strengthen the spinal and abdominal muscles. When definite deformity is present, attempts should be made to correct this, or to compensate for it if it is incorrectable. Correction is carried out chiefly by gymnastics and physiotherapy. When severe deformity is present, a corset may be used, as well as heat, massage, and exercises.—*John G. Kuhns, M.D., Boston, Massachusetts.*

INTRAPELVIC PROTRUSION OF THE ACETABULUM. B. N. Balakrishna Rao. *The Indian Journal of Surgery,* VI, 175, 1944.

The author discusses non-traumatic progressive protrusion of the acetabulum and the femoral head into the pelvis. The condition was first described by Otto in 1824 as "an abnormal gouty manifestation". Six new cases of this rare condition are reported, and the roentgenographic aspects are emphasized. Rao believes that it is probably inflammatory in origin, rather than being a developmental anomaly. He particularly recommends in the treatment of this condition Smith-Petersen's operation of acetabuloplasty, reported in *The Journal of Bone and Joint Surgery* (XVIII, 869, 1936), as this prevents further protrusion.—*Robert M. Green, M.D., Boston, Massachusetts.*

OSTEO-SPONDYLOSIS CONDENSANS HEREDITARIA. R. J. Weingarten and G. Politzer. *The Indian Journal of Surgery,* VII, 1, 1945.

The authors describe a hereditary skeletal disease, not previously recognized, for which they propose the name of *osteo-spondylosis condensans hereditaria.* Examination of three brothers revealed bilateral bone changes, consisting of pronounced thickening and condensation of the flat bones and, to a lesser extent, of the long bones. Exostoses and ossification of ligaments and muscle insertions were observed. Concurrent involvement of the central nervous system, simulating the syndrome of amyotrophic lateral sclerosis, was an outstanding feature. In the patients studied, abnormal clinical signs appeared in the third decade of life and progressed in the course of about ten years toward complete invalidism. Excellent roentgenograms illustrate the article.—*Robert M. Green, M.D., Boston, Massachusetts.*

THE TREATMENT OF SPONDYLOLISTHESIS. Walter E. Dandy. *The Journal of the American Medical Association,* CXXVII, 137, 1945.

The author continues to advance his method of spine fusion as the superior means of obtaining stabilization of the vertebrae. This study was begun with the thought that fixation of opposing vertebrae resulting from complete removal of an affected disc at the site of the spondylolisthesis would produce a much simpler and more effective fusion of the spine than the customary fusion with bone grafts. The following unexpected conclusions have resulted from such a study on patients operated upon for spondylolisthesis: (1) that the spondylolisthesis is usually responsible for only part and at times none of the symptoms; (2) that in most (not all) instances it is not the spondylolisthesis or even the disc at its site that causes the symptoms, but rather another disc or discs; and (3) that cure usually depends more upon removal of the other disc or discs than on the one at the site of the spondylolisthesis, though this too must be extirpated.

The principal reasons for these conclusions are listed, and it is the author's impression from his analysis that the spondylolisthesis is but an incident in the field of ruptured discs, and that, on the whole, while it causes its share of symptoms, it causes less than the contiguous disc or discs. The reason for the development of spondylolisthesis is considered to be precisely the same as for defective discs,—that is, the outward shift in the lateral articulations in the lower three lumbar vertebrae, nearly always most pronounced at the fifth lumbar. Here the joint is frequently turned outward 90 degrees from the direction of those at the first and second lumbar vertebrae, and in addition the joint is sometimes flat and vertical and with little or no flanges to keep the joint surfaces from slipping. The signs and symptoms of spondylolisthesis are precisely the same as those of defective discs without spondylolisthesis; only the roentgenographic appearance makes the differential diagnosis.

He then enumerates his points of dissatisfaction with spine fusion by autogenous grafts: (1) It is a prolonged major operative procedure; (2) it is necessary for the patient to be hospitalized in a cast for two or three months; (3) many grafts are unsuccessful and many absorb; (4) infection is a real danger, with frequent loss of all of the graft, making subsequent operation for removal of discs difficult; and (5), the graft is contra-indicated and useless because it merely covers up the offending discs and adds nothing to the fusion that follows complete removal of the discs. Following the author's disc operation, there is no need for a cast, the patient can leave the hospital in a week to ten days, and a light corset is advised for two or three months.

The three most important items in the author's treatment by removing the discs are: the complete removal of the affected discs; the recognition of multiple disc involvement; and the recognition of small (concealed) disc lesions. These three items are enlarged upon, and should be read in the original by all interested in the disc problem. Experiences similar to those of Dandy, if reported from another clinic, would strengthen the many assertions made by him, and should prove an advance in the care of these patients.—*H. H. Beckering, M.D., Dallas, Texas.*

One Stage Combined Resection of the Ribs and Spinal Fusion for Severe Scoliosis. William H. Bickel, John J. Hinchey, and O. Theron Clagett. *The Journal of the American Medical Association,* CXXVII, 139, 1945.

This paper is based on eleven cases of scoliosis in which resection of ribs and immediate spine fusion were performed to correct the deformity of the thoracic wall and arrest the scoliosis. The ages of the patients varied from eleven to twenty-two years; the average age was sixteen years. Three patients had congenital scoliosis, one, as a result of poliomyelitis; the remaining seven cases were idiopathic. Previous treatment had consisted of the usual conservative orthopaedic measures. The eleven cases were operated upon over a period of thirteen years; the last eight, in the past four years.

Preoperative treatment consisted of traction applied to the head and feet on a hyperextension frame for about ten days. Postoperatively, the patients were kept on a straight Bradford frame for the next four weeks. Then a body jacket was applied with the aid of the Goldthwait frame, after which the patient was ambulatory for one week. After these seven weeks, a cast extending from the chin and occiput to the iliac crests was applied under vertical suspension. This cast was worn for about four months. This was followed by a corset or Taylor brace for another six months, at which time swimming and breathing exercises were begun.

No correction of the curve by turnbuckle jackets or like methods was attempted. The number of involved ribs ranged from three to six. Usually from two to five inches of the ribs was resected, depending upon the relation of the rib to the convexity of the curve. The number of vertebrae fused ranged from eight to fourteen,—the whole thoracic vertebral curvature was grafted in each instance. Lumbar vertebrae were included in the grafting procedure in all but two cases.

Blood transfusions were used as indicated. The only complication was pleural effusion in three cases. In all cases, bone fusion was complete at the end of six to nine months. When there was regeneration of the resected ribs from the periosteum, the new portion conformed to the corrected contour of the thoracic wall.—*Brandon Carrell, M.D., Dallas, Texas.*

The Clinical Diagnosis, Prognosis and Treatment of Acute Hematogenous Osteomyelitis. Frank D. Dickson. *The Journal of the American Medical Association,* CXXVII, 212, 1945.

The facts presented by the author are based on a study of 295 cases of acute hematogenous osteomyelitis treated over a period of the last fifteen years. The staphylococcus is the offending organism in about 90 per cent. of the cases, usually the hemolytic staphylococcus aureus. The next most common organism found in culture is the streptococcus; occasionally a pneumococcus is found. In children under two years of age, the streptococcus is far more frequently found,—from 40 to 50 per cent.

The pathogenesis of the bone lesion is thoroughly discussed, and is clearly outlined; the theories as to the reason for the location of the bone abscess are explained. The clinical picture of the patient is well described and discussed. The usual laboratory findings are mentioned, and the differential diagnosis consists of: pyarthrosis, cellulitis, and rheumatoid arthritis.

The prognosis depends upon whether the case is one in which there is a transient bacteriaemia with the formation of a local bone abscess, or whether it is one in which a true septicaemia is present with pyaemia. In the former, the prognosis as to recovery is good; in the latter, it is grave, and a fatal outcome is a frequent result. The prognosis, so far as healing of the local bone focus is concerned, is poor. A great majority of the patients three years of age or older pass on to the chronic stage; in infants, however, there is little tendency for the disease to become chronic. The difference in the behavior of bone in extremely young children compared with older children and adults has been considered due to the following: The infection in young children is frequently a streptococcus; the large cancellous spaces in the bones of the infant allow the infection to pass more readily from the site of origin into the subperiosteal space, and the periosteum, being loosely attached in the infant, separates readily or ruptures, thus affording early drainage for the infection and ensuring minimal bone destruction; dead bone in young children absorbs very quickly, and formation of new bone is rapid.

Treatment in the infant should be directed toward the patient as a whole, and should be conservative, little attention being paid to the bone. Supportive treatment, prevention of dehydration, and immobilization of the extremity are the essentials. Antistaphylococcus serum should be administered, and the sulfonamides or penicillin should be used. Local treatment of the bone should be guided by the pathology present. Drainage by aspiration, incision and drainage of the soft-tissue abscess, and drilling and drainage of the bone are the means at hand, and they should be as conservative as possible.

Treatment in children over two years of age, in adolescents, and in adults should be carried out

along several lines,—general supportive measures, chemotherapy, administration of staphylococcus antitoxin, and management of the local bone disease. Parenteral fluids and blood transfusions, relief of pain by analgesics or opiates, staphylococcus antitoxin, sulfonamides, penicillin, and possibly bacteriophage should be used.

The differences of opinion as to the management of the local bone disease in these older patients are discussed. The author favors drainage of the bone abscess as soon as septicaemia is controlled and the general status is good.—*D. K. Barnes, M.D., Dallas, Texas.*

Aseptic Necrosis of the Epiphyses and Short Bones. Roentgen Studies. Howard P. Doub. *The Journal of the American Medical Association,* CXXVII, 311, 1945.

Areas of necrosis involving the epiphyses and also the primary centers of ossification in certain of the short bones have been described by different observers, and the name of the original observer has been attached to the lesion. These diseases have been known also under more general headings,—such as, epiphysitis, osteochrondritis, and subchrondral necrosis. It is now generally accepted that they represent the same underlying pathological process, although there is no general agreement as to the exact etiological agent.

The following are the theories advanced to explain the occurrence of areas of necrosis in the short bones and epiphyses: endocrine dysfunction; trauma; vascular occlusion, induced by trauma; and embolic vascular occlusion. These lesions are considered to be those of aseptic necrosis. There is actual death of the ossifying nucleus, which is followed by fragmentation, irregular absorption, and finally by replacement through so-called creeping substitution or recalcification. The necrotic bone in children is nearly always replaced by new bone, and the replacement proceeds more rapidly than in adults. The cartilage may show evidence of nutritional disturbance in places, but in large part it remains alive and may become thicker than normal, taking part in further epiphyseal growth after the necrotic bone has been replaced.

The author discusses concisely the following: osteochrondritis deformans juvenilis of the femoral head; slipping of the upper femoral epiphysis; epiphysitis of the tibial tubercle; aseptic necrosis of the tarsal scaphoid; infraction of the head of the second metatarsal; and kyphosis dorsalis juvenilis. No additional knowledge is presented, but this article is an excellent review of the subject.

A list of the various lesions, and the date of the first description of each by the author given the credit for its discovery, is included and is very interesting and valuable.—*D. K. Barnes, M.D., Dallas, Texas.*

The Clinical Diagnosis, Treatment, and Prognosis of Epiphysial Disturbances in Childhood. Wallace H. Cole. *The Journal of the American Medical Association,* CXXVII, 318, 1945.

The roentgenological aspects of this subject having been ably presented in the paper by Doub, the present author has confined himself to the clinical aspects and management of the various osteochrondroses, as they are officially termed.

Osteochrondrosis of the femoral head is common, and is often diagnosed by the family physician on the clinical findings. About 85 per cent. of the cases occur in males from three years to teen age; an onset after the age of twelve is very rare. The clinical findings are reviewed, and the various means of treatment by non-weight-bearing by the softened femoral head are presented. Prognosis depends upon the amount of deformity of the femoral head produced by weight-bearing.

Slipping of the proximal femoral epiphysis may be confused clinically with osteochrondrosis of the same epiphysis, but it occurs twice as often in boys as in girls; and, in about 70 per cent. of the cases, the body build resembles that of the Fröhlich type of individual. The smaller percentage of patients are apparently normal physically, or are the tall, thin, and rapidly growing type. The posterior and inferior displacement of the head is corrected by strong skeletal traction, by manipulation, by open reduction, or by osteotomy of the neck of the femur. The position must be maintained until the epiphysis closes, and this may be hastened by various procedures. Prognosis depends upon the correction obtained, and upon the configuration of the joint components.

Vertebral epiphysitis does not occur until puberty, as the epiphyseal plates develop at that time. Most cases are seen in boys between fourteen and seventeen years of age. The usual symptoms and findings are reviewed. Treatment is directed toward the prevention or correction, if possible, of the deformity of the increased dorsal kyphosis, until the spinal epiphyses unite with the bodies of the vertebrae.

Osteochrondrosis of the tibial tubercle is seen usually in active adolescent boys and does not lead to permanent disability. The signs and symptoms are reviewed, and the various means of treatment, aimed at relieving tension on the patellar tendon, are presented. Apophysitis of the os calcis never has any residual disability, and it is treated by reducing the pull of the tendo achillis. Osteochrondrosis of the head of the second metatarsal is treated by rest and protection until the epiphysis unites, when there is no longer any disability.

The author recommends the concomitant use of thyroid, although he does not believe it to be a specific. In the discussion of these papers, W. Edward Chamberlain questioned the use of the term aseptic necrosis for the various osteochrondritides. Dallas B. Phemister defended the use of the term necrosis and briefly reviewed the pathology.—*Brandon Carrell, M.D., Dallas, Texas.*

Rassasivaushysia metalichesky splav "osteosintesit" kak material dlia skreplenia kosti pri perelomach (An Absorbable Alloy, "Osteosynthesit", as a Material for Bone Fixation in Fractures). V. V. Troitsky i D. N. Zitrin. *Khirurgyia,* VIII, 41, 1944.

An alloy bearing the name of osteosynthesit was made by the authors. Their intention was to create a metal capable of absorption by the end of the period of consolidation in fractures.

The alloy consists of magnesium, with the addition of minute quantities of cadmium. Experimental investigations showed that the osteosynthesit plates introduced into the animal body immediately reacted with the surrounding tissues, producing magnesium salts and free hydrogen. No local irritation occurred, however. The formation of magnesium salts stimulated the development of bone callus. The rate of absorption for a plate two millimeters thick is such that it retains its mechanical efficiency for from six to eight weeks in wounds with normal acidity. The plate is completely resorbed in from ten to twelve months.

In wounds with increased acidity the rate of absorption is hastened, but so is the rate of bone consolidation. In the presence of neutral or alkaline reactions, the plates either do not absorb or the resorption is very slow. The authors state that out of thirty-four reported clinical observations, twenty-five were successful; the remaining nine were not satisfactory. However, the cause of failure in the nine cases could not be attributed to the alloy.

Further experiments are being conducted by the authors with various nails, screws, plates, hooks, wire, and hemostatic clips for the brain, and some of these have already been used successfully in human surgery.—*Emanuel B. Kaplan, M.D., New York, N. Y.*

A New Method of Digital Skeletal Traction. Thomas B. Quigley and Marshall R. Urist. *Medical Bulletin of the Office of the Surgeon, European Theatre of Operations* (Publication Restricted to Officers of the United States Army), No. 30, p. 56, Apr. 1945.

The authors point out the disadvantages of the various devices in common use for digital skeletal traction, and describe a new technique which they have devised and found satisfactory in their experience with over fifty fingers.

The absence of important structures in the middle third of the dorsum of the middle phalanx permits insertion of the authors' skeletal traction device. Through a very short incision in the skin, and under local anaesthesia, a small drill hole is made through the cortex of the dorsum of this phalanx, and a piece of wire, bent to the shape of a fishhook (or a small No. 4 fishhook, the barb of which has been removed), is inserted into the medullary cavity of this phalanx. Elastic traction is applied to a loop at the end of the shank of the hook-shaped wire. Motion of the metacarpophalangeal joints is carried out passively by the surgeon, through a complete range of motion, ten or fifteen times daily, beginning from five to seven days after the insertion of the hook. Active exercise of the interphalangeal joints is instituted, under supervision, as quickly as the condition of the hand permits. The usual roentgenographic check of the position of the fragments is carried out, and the tension and line of pull of the elastic are adjusted to correct angulation or distraction.

Tenosuspension Operation for Habitual Dislocation of the Shoulder. M. S. Henderson. *Proceedings of the Staff Meetings of the Mayo Clinic,* XIX, 5, 1944.

The author reports fifty-five tenosuspension operations for recurrent or habitual dislocation of the shoulder. The operations were performed over a period of nineteen years. The primary cause of dislocation varied greatly, including almost every conceivable type of trauma. The operation is an extra-articular suspension accomplished with the aid of a free transplant of the peroneus longus tendon. The tendon is used because it is stronger and handled more easily than fascia lata.

The technique of the operation is as follows: The incision through the skin may be of the saber type, two straight incisions, one in front and one posteriorly, or four small incisions. Next, holes are drilled through the tip of the acromion process and through the head of the humerus. The latter hole should be sufficiently far out on the greater tuberosity to prevent opening the joint. After the drill holes are made, the tendon transplant is removed from the leg, via two small incisions, one just above the outer border of the foot where the peroneus longus tendon crosses to the plantar aspect, and the other ten centimeters above the lateral malleolus. The tendon is then severed above in a Z fashion and drawn out through the incision below. Half of the diameter of this tendon can then be taken; it should be six to eight inches long. The remaining portion of the tendon is replaced and is resutured at the site of the Z of the proximal portion of the peroneus longus. The piece of tendon removed is threaded through the previously prepared drill holes. With the arm at the side, the tendon is sutured together after a fair amount of tension is placed on the structure. Care is taken that the tendon transplant is deeply placed

beneath the deltoid muscle and rests snugly down on the joint capsule. Thus two suspensory ligaments are constructed, one anterior and one posterior.

The patient is put to bed, and a sling holds the arm to the side. No abduction is permitted for about two weeks, and then only 20 to 25 degrees. Right-angle abduction is not allowed for three months.

Of fifty-five operations on fifty-one patients, fifty, or 91 per cent, were successful. The average age was 25.6 years. There were eleven females, and forty males. There was little if any restriction of motion. In this group the time interval since the operation varied from fifteen months to nineteen years. Three failures in this series were in epileptic patients—*J. L. LeNoir, M.D., Iowa City, Iowa.*

SIGNIFICANT SKELETAL IRREGULARITIES OF THE HANDS. John F. Holt and Fred. J. Hodges. *Radiology,* XLIV, 23, 1945.

Routine roentgenographic examination of the hands is as valuable a diagnostic procedure as ophthalmoscopy in the recognition either of generalized systemic disease or of a localized pathological process in some remote portion of the body. Great care should be used in making the films so as to produce a result of the greatest value. Todd's monograph on skeletal maturation of the hand is not only a valuable means of determining bone development, but also constitutes an excellent norm to be used for comparative purposes.

Many endocrine disturbances are revealed by bone changes in the hands. Acromegaly presents broad spade-like hands with overgrowth of the terminal phalangeal tufts, prominence of bony protuberances along the shafts of the metacarpals and phalanges, and a peculiar soap-bubble pattern of distorted trabeculae in the bone ends. Cretinism is revealed by delayed epiphyseal ossification, and by bands of increased density in the ends of the tubular bones. Response to therapy is indicated by subsidence of these changes. Mongolian idiocy can be differentiated from cretinism on the basis of bone changes alone. In mongolism the findings are those of relatively normal bone development and congenital shortening of the middle phalanx of a stubby curved fifth finger. Other findings of endocrine disturbances are: the fibrocystic bone lesions of hyperparathyroidism and of polyostotic fibrous dysplasia; and the peripheral degenerative changes of progeria.

Congenital anomalies as seen in the hands are not only local changes, but may also be a part of more widespread disturbances. Dysostosis cleidocranialis shows characteristic changes in the hands. The ungual phalanges are short and cone-shaped. There is also failure of development of the usual prominent cancellous tufts. The metacarpals, as well as the proximal and middle phalanges, have supernumerary epiphyses which fuse earlier in life than do the normal. All epiphyses appear broader than normal, particularly in the terminal phalanx of the thumb. In achondroplastic dwarfs, the second to fifth metacarpals are short, stubby, of nearly equal length, and the ends are often quite bulbous. The phalanges likewise are short and broad. In Morquio's disease, the ends of the metacarpals and phalanges are grossly irregular, and the carpal bones display a crenated appearance as well as delayed skeletal development. Hurler's syndrome (gargoylism) shows short broad metacarpals, middle phalanges with an arrowhead configuration, and a coarse prominent trabecular pattern. Arachnodactylia is striking because of the exceedingly long metacarpals and phalanges, and the presence of supernumerary epiphyses. In this disease, congenital dislocation of the lenses of the eyes, and congenital heart disease should be looked for.

The majority of changes seen in trophic disturbances are quite similar, and consist in slow spontaneous amputations of the phalanges. In addition to this type of resorption, there may be scleroderma and calcinosis, as well as extensive osteoporosis of the juxta-articular portions of the phalanges and metacarpals, soft-tissue contractures, and soft-tissue calcium depositions.

Chronic granulomata may be local lesions of the hand or may serve to direct attention to a systemic involvement, as in spina ventosa or tuberculous dactylitis. Boeck's sarcoid and osteitis tuberculosa multiplex cystica are more likely the same lesion, and have only an obscure relation to tuberculosis. These lesions are not always punched-out and cystic in character, but may begin merely as a coarsening of the bony trabeculae, following which areas of both cortical and central destruction appear.

Chronic pulmonary or mediastinal disease reveals itself readily in the fingers as pulmonary osteoarthropathy. In addition to the soft-tissue clubbing, periosteal proliferation is noted along the shafts of the metacarpals and phalanges. Its occurrence is greater in non-tuberculous lesions. Since its progression, regression, and severity vary with the course of the chest lesion, roentgenograms of the hand can be used as an indication of the course of the thoracic lesion. These changes are particularly noted in the periosteal proliferation.

Though the moth-eaten lesions of leukaemia are more commonly seen in the long bones, they may also be seen in the hands. In erythroblastic anaemia, the findings in the hands are clear-cut. The metacarpals and phalanges take on a characteristic rectangular shape, the medullary canals are dilated, the cortices are thinned, and the shafts are traversed by a coarse irregular meshwork of dense, broadened trabeculae standing out against the background of osteoporosis.

The chronic arthritides have their characteristic lesions. Gout shows its typical intramedullary and extramedullary destruction secondary to tophi. Chondromata when seen should direct attention to

other bones in the body. Osteopoikilosis, osteopetrosis, and melorheostosis are seen. Tuberous sclerosis sometimes produces rarefactions in the phalanges.

The authors include with the article a series of roentgenograms illustrating many of these findings. —*William H. Wright, M.D., Santa Monica, California.*

TUBERCULOSIS OF THE GREATER TROCHANTER AND ITS BURSA. P. C. Briede. *Radiology*, XLIV, 32, 1945.

Tuberculosis of the greater trochanteric bursa is rare, and is usually secondary to tuberculous osteomyelitis of the greater trochanter, which itself is often associated with tuberculosis elsewhere in the body, either active or inactive. Wieting in 1904 demonstrated the presence of the tubercle bacillus as the etiological agent in trochanteric bursitis, declaring that the primary infection spread from the trochanter to the bursa.

The condition has been found in all ages and in both sexes. Trauma was thought to be the most constant precipitating factor. The usual complaint was mild pain in the involved leg over a long period of time. Slight swelling was present behind the greater trochanteric area, with tenderness to pressure. There was no heat or redness. Weight-bearing was usually painless, and motion of the hip was free. However, on extension into the neck and hip joint, motion was limited, and weight-bearing was painful. Draining sinuses were common. Active or inactive tuberculosis in other portions of the body was a common finding. Early roentgenographic evidence consisted of a small fleck of calcium in the bursa, or a minimal area of destruction in the trochanter. (These findings are best demonstrated with a soft-tissue technique.) The later and more usual appearance on the roentgenogram was: an area of destruction in the greater trochanter, with an area of osteoporosis in the shaft; soft-tissue swelling, with deposition of calcium; and occasionally a sequestrum lying adjacent to the trochanter. Simple inflammatory bursitis is differentiated by the acuity of symptoms, and the rapidity of response to simple therapeutic measures. Non-specific osteomyelitis of the trochanter may be identical in appearance, but the past history is indicative.

Effective therapy consists in total excision. When the disease is limited to the bursa or involves only a small portion of the trochanter, excision results in cure. Recurrences are common in a high percentage of the cases. Extension into the hip joint is a serious complication. Four cases are presented to illustrate these points.—*William H. Wright, M.D., Santa Monica, California.*

CONTRIBUCIÓN AL ESTUDIO DE LA LUXACIÓN DE RÓTULA (Dislocation of the Patella). L. Sierra Cano y A. Sánchez Trallero. *Revista Española de Cirugía, Traumatología y Ortopedia*, I, 112, 1944.

The authors refer to the lack of unanimity as to the nomenclature, the pathomechanics, or the treatment of dislocation of the patella. It is a rare deformity, only two cases having been observed among 1,800 patients in the authors' clinic. They prefer Buzby's classification of congenital, traumatic, and structural (following poliomyelitis, rickets, and genu recurvatum). Exaggeration of physiological valgus tends to dislocation; but dislocation is also seen in genu varum. Aplasia of the external condyle is another etiological factor, as may be the small size of the patella. Internal torsion of the lower end of the femur is sometimes found. Alterations in the ligamentous apparatus, such as rents in the articular capsule, contracture of the soft parts, and shortening of the vastus lateralis and iliotibial band, are also causative factors. The different causes play a part in various cases.

Indications for treatment vary according to the period of evolution and the seriousness of the lesion. Operation is indicated only at the first appearance of disturbance in function, and not when the deformity is first discovered, because frequently it causes no symptoms throughout life. Conservative treatment of congenital dislocation of the patella consists in physiotherapy for the quadriceps apparatus. Many operations have been described stressing one pathological lesion,—such as osteotomy of the femur, correcting the valgus and the rotation, and raising the external femoral condyle, which is a difficult procedure and leaves much to be desired; it should not be used before growth is completed. There are several operations on the capsular ligamentous apparatus. Capsulorrhaphy has not given good results. Anchoring of the patella by fascia lata to the internal condyle has been successful. Following its introduction by Roux in 1888, many surgeons have transplanted the patellar tendon. This has been criticized, because it may limit the power of extension of the patella.

The authors' two cases are reviewed in detail. One patient was a boy of eight years, with frequent dislocation of the patella. There was no valgus or flattening of the condyle. A myoplastic procedure at the expense of the vastus medialis held the patella in good position, and a good functional result was obtained.

A second patient, eighteen years of age, had had two dislocations. There was no arthritis or functional alteration. Therefore, intervention was not indicated.—*John G. Kuhns, M.D., Boston, Massachusetts.*

LA OSTEOPERIOSTITIS BRUCELÓSICA (OSTEOPERIOSTITIS IN BRUCELLOSIS). Carlos A. Videla y José A. Scodeller. *La Revista de Medicina y Ciencias Afines*, VI, 893, 1944.

Most of the cases of brucellotic osteoperiostitis are due to brucella melitensis. The chief symptom is pain, usually about one of the joints. It may appear at any stage of the disease. The joints most fre-

quently affected are the spine and sacro-iliac joints, and there the disease process produces an osteitis of the vertebral body, with a flattening or loss of disc space, and occasionally a paravertebral abscess. It is comparable to Pott's disease. Sciatica may accompany sacro-iliac involvement.

Osteitis and osteoperiostitis are less common. Clinically, such conditions occur as inflammatory swellings along the shafts of the long bones. Occasionally, a purulent collection forms, which may drain spontaneously or have to be drained, but which usually regresses spontaneously. The inflammatory reaction in the medullary canal produces the deep-seated, boring pains.

Pathologically, the first phase of osteoperiostitis is a mild decalcification of the cortex, around which a thickened sleeve of periosteum forms. Sequestration does not occur. As the lesion heals, the periostitis may undergo regression, or may result in hyperostotic periostitis. Some cases are accompanied by a "cold" abscess, and others by an acute "pyogenic" swelling, depending on the virulence of the organism.

In addition, the authors report a case of brucellotic periostitis, in which the periostitis in the long bones occurred and disappeared with each febrile reaction. This is extremely unusual.—*Victor Richards, M.D., San Francisco, California.*

LUXATIONS PÉRILUNAIRES RÉCENTES (Recent Perilunar Dislocations). R. Soeur. *Revue d'Orthopédie et de Chirurgie de l'Appareil Moteur,* XXVII, 5, 1941.

To eliminate confusion in the nomenclature of traumatic displacements of the lunate bone, the author groups them under the name of perilunar dislocations. These are divided into displacements of first, second, and third degree.

In the first, the lunate bone retains its relation to the distal end of the radius, but loses contact with the head of the capitate. In the author's series, these dislocations were always accompanied by fractures of the scaphoid. Closed reductions were usually obtained, although immobilization was prolonged on account of the scaphoid fracture.

In the second-degree dislocations, the lunate is enucleated from under the radial articular surface, but still remains in front of its normal place in the carpus, because the anterior radiolunar connection is not torn. These dislocations were observed without fractures of the scaphoid, but constantly presented signs of pressure on the median nerve. These fractures of the scaphoid required open reduction with immobilization for a short time.

In the third group, the lunate is completely dislocated along the surface of the radius, losing contact with the carpus because the ligaments are completely torn. The dislocation is always accompanied by additional fractures and dislocations of one or more bones of the carpus.—*Emanuel B. Kaplan, M.D., New York, N. Y.*

LE TRAITEMENT DU PIED CONVEXE VALGUS CONGÉNITAL (Treatment of Congenital Convex Pes Valgus). J. Leveuf. *Revue d'Orthopédie et de Chirurgie de l'Appareil Moteur,* XXVII, 129, 1941.

The name of the deformity was proposed by Lamy and adapted by the author for reasons of analogy and difference with the known deformity of talipes planovalgus.

The characteristics are: An equinus of the hind foot; dorsiflexion of the forefoot, the axis of rotation being in the midtarsal joints; strong abduction of the metatarsals in relation to the hind foot, creating a concavity of the external border of the foot and a convexity of the medial border, centered over the head of the astragalus.

The author recommends a two-stage procedure:

1. Lengthening of the retracted peroneal tendons and the common extensors. Wedge osteotomy with a medial base of the midtarsal joints. Reinsertion, under tension, of the tendon of the tibialis posterior muscle. In case of severe pronation of the forefoot, a transplantation of the common extensor to the medial side of the foot may be useful.

2. Lengthening of the Achilles tendon for correction of the equinus.—*Emanuel B. Kaplan, M.D., New York, N. Y.*

A PROPOS DE 21 CAS D'OSTÉOCHONDRITE DE L'ÉPIPHYSE FÉMORALE SUPÉRIEURE "COXA PLANA" (On Twenty-One Cases of Osteochondritis of the Upper Femoral Epiphysis—Coxa Plana). J. Bouquier, J. Clénet, et H. Leveau. *Revue d'Orthopédie et de Chirurgie de l'Appareil Moteur,* XXVII, 285, 1941.

According to the study made by the authors, osteochondritis of the superior femoral epiphysis is a non-inflammatory, acquired disease. It follows a congenital malformation of this region and is due to several elements of a predisposing anatomical nature. The acetabulum is congenitally the most frequently affected, next the head, and then the neck of the femur. Due to the congenital malorientation, the normal axis of the hip joint is changed. With the beginning of standing and walking, constant mild trauma takes place, which has repercussions on the contiguous bones of the joint, because the axis of the joint is not normal. Accidental injury aggravates the condition. If the central artery of the femoral head and the nerve supply to the joint are affected, the venous circulation becomes involved, suddenly or gradually. The veins of the head and neck have no anastomoses in early childhood. This functional disturbance of the return circulation is responsible, according to the authors, for the lesions characteristic of epiphysitis of the upper femoral epiphysis. Reorganization of the venous return takes place slowly.

During this period of evolution, however, the softened head is compelled to abandon the irregular acetabulum in part, and to adapt itself to a new joint.

Thus the head of the femur, deformed by osteochondritis, is in itself not a coxa plana, but a late adaptation of an osteochondritic head to an acetabulum flattened by coxa plana.—*Emanuel B. Kaplan, M.D., New York, N. Y.*

La section des branches articulaires du nerf obturateur dans le traitement de l'arthrite chronique de la hanche (Division of the Articular Branches of the Obturator Nerve in the Treatment of Chronic Arthritis of the Hip). L. Tavernier et P. Truchet. *Revue d'Orthopédie et de Chirurgie de l'Appareil Moteur*, XXVIII, 62, 1942.

The authors report their results in twenty-one patients with painful chronic arthritis of the hip, relieved of pain by a single division of the obturator nerve supplying the capsule. In nine patients the result was very good, seven were completely relieved of pain, two were improved, and in only three was there complete failure.

The procedure is indicated in all forms of chronic arthritis—with pain, alone or accompanied by congenital deformity, due to trauma, or secondary to operative interference. The results obtained are immediate and remain satisfactory.

The purpose of the operation is to eliminate the sensory nerve supply to the capsule. The method was first proposed by Camitz in 1933; the first patients were operated upon by the authors in 1936.

The nerves supplying the capsule of the hip joint have posterior branches (from the sciatic, posterior cutaneous nerves, and the nerve of the quadratus femoris), and anterior branches (from the femoral and obturator nerves).

The most important branches transmitting sensory stimuli come from the deep ramus of the obturator nerve in its passage through the obturator foramen.

The obturator nerve is approached through an incision from below the pubic spine to the apex of Scarpa's triangle. The saphenous vein is retracted, and the space between the long adductor and pectineus muscles is located. On separating those two muscles, one finds the superficial branch of the obturator spread on the surface of the adductor brevis. Following this branch upward, the deep branch of the obturator is located and avulsed by rolling it around the jaws of an artery forceps.

In the opinion of the reviewer, this procedure may be of great practical interest.—*Emanuel B. Kaplan, M.D., New York, N. Y.*

Les lésions de la tête du fémur provoquées par les tentatives prolongées de reduction orthopédique dans les luxations congénitales de la hanche (Lesions of the Head of the Femur in Congenital Dislocation of the Hip Produced by Prolonged Conservative Orthopaedic Treatment). J. Leveuf et R. Leroux. *Revue d'Orthopédie et de Chirurgie de l'Appareil Moteur*, XXIX, 65, 1943.

The relationship of deformity of the head of the femur to closed reduction of congenital dislocation of the hip is not well established. There are few reliable reports based on actual microscopic studies of the deformed heads of the femur.

The authors made a microscopic study of biopsy material from seventeen patients. In fourteen patients, competent orthopaedic surgeons made several attempts toward closed reduction with long immobilization, but perfect reduction was not obtained in any instance. The patients were subsequently operated upon, and a biopsy of the cartilage of the head was done in each case. The material thus obtained constituted the subject of this study. For purposes of control, a biopsy was performed on three patients who had an open reduction immediately following the first unsuccessful attempt at closed reduction. In the three control cases, the cartilage was found to be normal. The fourteen patients treated were divided into three groups: (1) those immobilized after reduction of from four to twelve months; (2) those immobilized for from ten to sixteen months; and (3) those immobilized for from fourteen to thirty-nine months. After these periods of immobilization, it was found that the femoral heads were all deformed. In each group there were typical pathological changes of the cartilage.

The authors believe that the abnormal changes of the head are not due to injuries of the round ligament or synovia, but to prolonged pressure exerted on imperfectly reduced femoral heads.—*Emanuel B. Kaplan, M.D., New York, N. Y.*

Les formes atypiques de l'ostéochondrite infantile de l'épiphyse fémorale supérieur (Atypical Forms of Infantile Osteochondritis of the Upper Femoral Epiphysis). A. Aimes. *Revue d'Orthopédie et de Chirurgie de l'Appareil Moteur*, XXIX, 78, 1943.

The author describes six types of osteochondritis, besides the usual well-known type.

The usual type is characterized by flattening of the epiphysis, which becomes fragmented and broadened beyond the femoral neck. The epiphyseal plate is wavy and irregular, and the neck is shortened and enlarged. (Twenty-seven patients with these symptoms were followed.)

In addition, the author describes the hypertrophic type which presents, when healed, a very large, round head. Sometimes the head is larger than the acetabulum, and in these cases a secondary shelf is observed. Fourteen patients of this type were observed.

Another type is characterized by very long evolution, with no definite signs of healing for four or five years.

Calvé described a type with acute onset. Four patients of this type who were treated by the author had intermittent attacks of pain, in one instance accompanied by fever.

The author describes an acetabular type of osteochondritis, not involving the head. Seven patients in this group are mentioned.

Six patients tending to develop stiffness and ankylosis of the hip were also observed.

The sixth type is associated with congenital dislocation, and may be of the usual, or hypertrophic, form. Ten cases of this group were seen by the author, of which two were of the hypertrophic type.—*Emanuel B. Kaplan, M.D., New York, N. Y.*

L'ostéotomie sous-trochantérienne indications—résultats (Subtrochanteric Osteotomy: Indications and Results). R. Charry et G. Charry. *Revue d'Orthopédie et de Chirurgie de l'Appareil Moteur,* XXIX, 99, 1943.

Thirty osteotomies in twenty-five patients are reported. In twenty-four cases angulated plates were used for osteosynthesis.

The following are the conclusions of the authors based on twenty-four excellent results, one satisfactory, three doubtful, and two failures:

1. Osteotomies without bone fixation may lead to failure.

2. In cases of arthritis deformans, in addition to the osteotomy, a resection of the obturator nerve is very important.

3. It is important to immobilize both hips in plaster. The immobilization of the normal side should be maintained for at least twenty days.

4. One of the annoying complications is stiffness of the knee on the affected side, which should be prevented by early physiotherapy.

5. If the plating is satisfactory and the bones are not unusually porous, immobilization should not extend beyond forty-five days. After sixty-five or seventy days the patient should be able to walk.

6. In osteotomies for old dislocations of the hip or for pseudarthrosis of the neck of the femur, the angulation after osteotomy should be at least 90 degrees.

The operation is indicated in unreduced congenital dislocations, in arthritis deformans, irreducible traumatic dislocations, and pseudarthrosis of the neck of the femur.—*Emanuel B. Kaplan, M.D., New York, N. Y.*

Traitement des subluxations congénitales primitives de la hanche chez l'enfant (Treatment of Primary Congenital Subluxation of the Hip in Children). M. J. R. Barcat. *Revue d'Orthopédie et de Chirurgie de l'Appareil Moteur,* XXIX, 129, 1943.

The treatment of congenital subluxation depends on the age group of patients. The author recognizes three groups: (1) from birth to eighteen months; (2) eighteen months to eight years; and (3) eight to fifteen years.

In the first group, the treatment is prophylactic. In the presence of signs of femoral mobility, as indicated by the methods of Putti and Hilgenreiner, the treatment by abduction is indicated. In the presence of shallow acetabula only, the patient is kept under observation without treatment but with roentgenographic control every three months; he is not permitted to walk until complete restitution of the acetabula has taken place.

In the second group, the author believes that conservative treatment is entirely unsatisfactory. Operative treatment at the earliest possible age is recommended. The purpose of the operation is replacement of the head in the acetabulum, with a corresponding correction of the valgus and anteversion, by an appropriate wedge resection of the base of the neck.

In the third group, the author divides the treatment according to the type of deformity. If the acetabulum is well developed, a wedge resection of the base of the neck, correcting the anteversion, is sufficient. If the acetabulum is well developed but does not hold the head of the femur, a more prominent roof of the acetabulum is to be obtained by operation; and, simultaneously, a wedge resection of the base of the neck is performed to correct the valgus and the anteversion.

If the acetabulum is completely insufficient, the author recommends its reconstruction and also a derotation osteotomy, if anteversion is present; or a wedge osteotomy of the base of the neck if there is valgus in addition to the anteversion.

The author warns against neglecting the treatment of subluxation on one side, if there is a coexisting complete dislocation on the other side.—*Emanuel B. Kaplan, M.D., New York, N. Y.*

Treatment of Fractures of the Tibial Condyles. Robert A. Knight. *Southern Medical Journal,* XXXVIII, 246, 1945.

This series reports 134 cases of fractures of the tibial condyles, eighty-one treated conservatively, and fifty-three by operation. Conservative treatment is used when there is only moderate displacement, and not more than one-fourth-inch depression of the condyle. After reduction of the fracture and aspi-

ration of the joint, if distended, a plaster cast is applied for three weeks, followed by active motion and physiotherapy for three more weeks. Then a knee brace is applied, but weight-bearing is not allowed for ten weeks. Operative treatment is used, if there is appreciable depression of the articular surface. The cruciate ligaments, or collateral ligaments, may have to be repaired. The incision should be large enough to explore the joint cavity. The meniscus may have to be removed. After the depressed condyle has been elevated, a bone graft is necessary to hold it up in place. Internal pin fixation holds the graft and fracture in place. Cancellous bone taken from the femoral condyle makes an excellent graft. Malunited fractures are treated by osteotomy and bone graft.

Postoperative care includes a plaster spica with the knee slightly flexed. In two or three weeks, after the wound has healed, the cast is removed, and the leg is suspended in balanced traction for active and passive motion. Daily physical therapy is given, the patient being instructed in quadriceps exercises, and care is taken to prevent forcible flexion of the knee. After five or six weeks a long leg brace with limited motion at the knee joint is applied. Partial weight-bearing is begun after eight or ten weeks. Full weight-bearing is started after five or six months. The period of disability following operation in the cases in this series averaged seven to ten months.

Traumatic arthritis has been found to develop after a varying period of years in many instances following operative reconstruction of the tibial condyles.—*Fred G. Hodgson, M.D., Atlanta, Georgia.*

TRENCH FOOT. Frank K. Boland, Jr., Thomas S. Claiborne, and Francis P. Parker. *Surgery,* XVII, 564, 1945.

During the winter months in France, Belgium, and northern Italy many of our soldiers suffered from trench foot. This condition was manifested by pain and swelling of the feet, following exposure for long periods of time to wet and cold. The authors of this article report observations based upon the study of 125 of these patients at a general hospital.

The pathology of trench foot is quite similar to that of frostbite, immersion foot, shelter foot, and chilblain. The average time of continuous exposure to cold and wet by the men in this group was eleven days. Dry cold was much better tolerated than moist cold approximately at the point of freezing. Very few of the men had opportunity to change their socks during the period of their exposure, and the socks were usually wet. The swelling was more marked when the patients removed their shoes and their feet became warm. Simultaneously the pain increased.

Treatment consisted simply of elevation of the feet, which were kept dry and moderately cold. The covers were kept turned back in most instances. When pain and swelling had diminished, some exercises were encouraged. In the severe type, gangrene developed; and necrotic tissue had to be cut away. Eighty-two per cent. of these patients were able to return to duty after a period of treatment and convalescent care which averaged sixty-one days.—*Edward L. Compere, M.D., Chicago, Illinois.*

HOMOGENOUS CARTILAGE GRAFTS. Forrest Young. *Surgery,* XVII, 616, 1945.

This study was undertaken to determine the viability of various types of cartilage transplants. In a previous experimental study by the author, autogenous cartilage grafts were used and dogs were selected for the experiments. It was found that autogenous costal cartilage, when transplanted to the subcutaneous tissues in dogs, remained viable, and did not lose weight or volume for as long as one and a half years. It made no difference whether the cartilage was transplanted with or without perichondrium. Following these experiments, the author was able to examine an autogenous costal cartilage graft which had been used in the treatment of a woman for a nasal deformity twelve years previously. Microscopically, the cartilage appeared normal.

In this study, Young transplanted segments of costal cartilage from one dog to the abdominal wall of another; five pairs of dogs were used. A total of sixty pieces of costal cartilage were implanted in the abdominal walls of ten dogs; in each instance the cartilage was obtained from a donor dog. These grafts were removed at intervals and examined. A few of the cells had lost their nuclei, and a central area of bone formation had appeared in some of the cartilage grafts. The cross transplants, however, all remained viable, though some degenerative changes were present.—*Edward L. Compere, M.D., Chicago, Illinois.*

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